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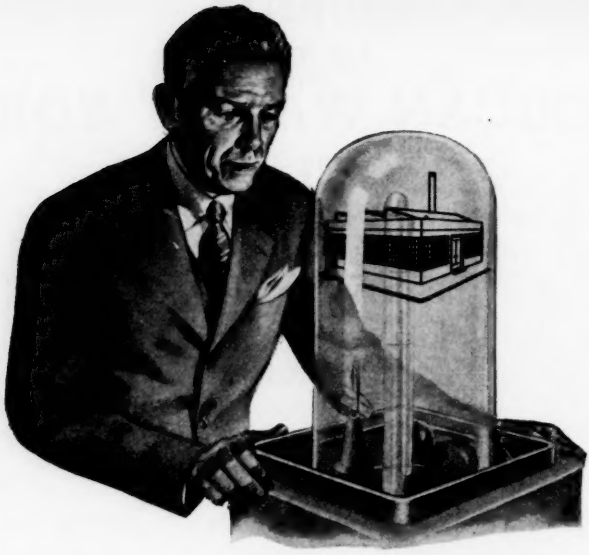

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Progress Report on Studies of Water Chlorination

By H. W. Streeter

UNDER authorization by the Director of the National Institute of Health, a study of water disinfection methods and their technical control, with special reference to requirements in military and war industry areas, was instituted at the U.S. Public Health Service Station of Stream Pollution Investigations at Cincinnati in April 1942. This study has dealt primarily with chlorination, but has also included consideration of possible alternative methods which might be available in the event of a shortage of chlorine owing to war conditions. The present report deals only with the work which has thus far been carried out on methods and control of chlorination, deferring until later a discussion of other disinfection processes which are being studied.

In carrying out the study of water chlorination, special attention has been devoted to the theory and practice of the "break-point" method, to which much consideration has been given recently by water treatment specialists. Another subject of particular interest has been the relative bactericidal efficiency of free chlorine and chloramines and the minimum residual concentrations of these two agents which are necessary to ensure complete disinfection of waters containing sewage bacteria. In this connection, chemical and electrometric methods of measuring chlorine residuals have been thoroughly studied, with a particular view to any improvements in such methods which might be possible. The entire study has been aimed primarily toward problems of water chlorination in military and other areas involved in the war effort, where extra precautions are necessary to provide adequate sanitary protection for water supplies.

Following a review of the recent literature on water chlorination, a series of preliminary experiments was undertaken for the purpose of determining the relative bactericidal rates observed with pure cultures of coliform

A contribution by H. W. Streeter, San. Engr. Director, U.S. Public Health Service Station of Stream Pollution Investigations, Cincinnati, Ohio.

bacteria under varying conditions of added and residual chlorine concentration, pH value and chlorine : ammonia ratio. Concurrently with these experiments, another series of chemical studies was undertaken on methods of determining significant chlorine residuals, using the standard ortho-tolidine and starch-iodide tests and also electrometric methods involving the measurement of progressive changes in the oxidation-reduction potential. A possibility investigated in this connection was the development of a practical colorimetric test for distinguishing free chlorine from chloramines in low concentrations. The standard ortho-tolidine and starch-iodide tests are not satisfactory for this, as they react to both free chlorine and chloramines.

Bacteriological Experiments

For the bacteriological part of the study, it was decided to use initially pure strains of coliform bacteria isolated from feces and sewage. Preliminary tests were carried out in order to determine the comparative resistance of various coliform strains to similar concentrations of free chlorine and chloramines. The results indicated, incidentally, that typical *Escherichia coli* were more resistant than intermediate strains and typical *Aerobacter aerogenes*. Considerable variation was observed in the resistance of different strains of the same groups of bacteria, though, for experimental purposes, it was possible to select strains which were fairly typical of each group as a whole. In further experiments now in progress, the comparative resistance of several pathogenic groups against that of the typical coliform strains is being studied.

In the early experiments, suspensions of coliform bacteria were exposed, for varying periods of time, to different concentrations of free chlorine and similar concentrations of chloramines, each being in pure solution. In undertaking to prepare solutions of free chlorine uncomplicated by the presence of chloramines, considerable difficulty was experienced initially in obtaining the necessary ammonia-free water, though a very satisfactory technique for doing so was developed. The results of these preliminary experiments brought out very strikingly the marked difference existing between the bactericidal power of free chlorine and that of chloramines. With free chlorine, concentrations as low as 0.05–0.10 ppm. killed all of the coliform bacteria within 2 or 3 min., whereas, with the same concentrations of chloramine, periods of 40–90 min. were required to produce the same killing effect. To kill all of the bacteria within periods of 2–3 min., concentrations of chloramine ranging between 2 and 3 ppm. were needed. From these results, it was indicated that free chlorine is 20–30 times more powerful as a bactericidal agent than chloramine. Later experiments confirmed this.

In connection with the experiments on exposure of bacteria to free chlorine, it was noted that with low concentrations of residual chlorine (0.10–0.20 ppm.), extremely rapid killing action occurred at pH values ranging from 6.0 to 7.0, all coliform organisms being killed within ½–2 min. In one experiment, 0.05 ppm. of free chlorine killed all bacteria in 3 min. At pH 8.0, the rate of killing action was about one-half that observed at pH 6.0–7.0, and at pH 9.0 the corresponding rate was about one-third. In chloramine solutions a similar general relation was observed between bactericidal rates and pH variations.

Break-Point Chlorination

In the experiments with break-point chlorination, the "residual" curves were followed through at different pH values and after various periods of contact between the chlorine and ammonia, ranging from 0 to 24 hr. At several points along each curve, bactericidal rates were observed, with different reaction periods as above indicated. Chlorine or chloramine residuals were determined in some of the experiments by ortho-tolidine, starch-iodide and electrometric methods in parallel. The results indicated a definite correlation between variations in observed rates of bactericidal action and corresponding variations in the chlorine residuals as determined by the three methods. This correlation was particularly well marked in respect to the measured oxidation-reduction potential, which shows a sharp upturn at the break-point. The highest killing rates along the pre-break-point section of the curve occurred near its crest, where the indicated concentration of chloramine was a maximum. Although these rates were high in comparison with those noted at other points of the curve prior to reaching the break-point, they were much lower than those observed immediately following the break-point, when free chlorine began to appear.

On the basis of chlorine : ammonia ratios, the rates of bactericidal action observed for complete bacterial kill ranged from about 5 hr. with a ratio of 1 : 1 or below to about 2 min. or less with a ratio of 11 : 1 or more. Ratios from 7 : 1 up to 12 : 1, when observed on the downward limb of the break-point curve, showed more active killing power than ratios of 5 : 1 or less, though, in the latter case, higher ortho-tolidine residuals were shown.

The observations with varying periods of contact between the chlorine and ammonia indicated that the reaction between these two substances is very rapid at pH 7 and over, but is progressively retarded at pH values below 7. Where this reaction is retarded, free uncombined chlorine may be present in the water for short periods of time, as evidenced by the extremely rapid rates of bactericidal action observed under these conditions. The practical significance of this observation is that, where conditions favor retardation in the chlorine-ammonia reaction, free chlorine may effect a powerful killing action on the bacteria initially present in the water over a short period of time, but, later, when the reaction has been completed, no free chlorine may be present and the bactericidal action is correspondingly reduced to that of chloramines, unless a sufficient amount of chlorine has been added to the water to carry it past the break-point. This phenomenon may explain to some extent the high bactericidal rates observed in chlorinated waters at treatment plants, where samples are collected near the point of application of chlorine.

A series of experiments on the bactericidal efficiency of sodium hypochlorite, in comparison with chlorine, was carried out in a buffered water at pH values ranging from 6 to 9. The results of these experiments indicated no significant difference between the bactericidal action of the hypochlorite and that of the chlorine solutions under similar conditions. Lower rates of bactericidal action were noted with increasing pH values up to 9, the range in observed times required to effect complete action being from less than 1 min. at pH 6.9 to about 10 min. at pH 8.9, with no ammonia present in

the water. In the presence of more than 0.1 ppm. of nitrogen as ammonia, successive increments of hypochlorite produced characteristic break-point curves, similar to those resulting from the addition of chlorine.

In connection with break-point chlorination, both with chlorine and hypochlorites, the assumption that free chlorine first appears in stable form immediately beyond the break-point was invariably confirmed by the results of the bacteriological tests at various points along the break-point curve. Aside from this evidence, no specific test was available in the early series of experiments whereby the first appearance of free chlorine could be detected, except the sharp upturning observed in the oxidation-reduction curve coincidently with passing the break-point. The shortcomings of the standard ortho-tolidine and starch-iodide tests in this respect are well known, as neither test ordinarily can differentiate between free chlorine and chloramines. The great practical value of a simple test whereby free chlorine could be detected in low concentrations either in the presence or in the absence of chloramines was, therefore, clearly recognized and a systematic effort was directed toward developing such a test, if possible.

Meanwhile definite progress had been made toward the development of a practical colorimetric test for free chlorine, after trying a large number of indicators. The result of this work has been the development of a simple and reliable colorimetric test for free chlorine, based on the use of a common dye, *p*-aminodimethylaniline hydrochloride, originally proposed by Koltoff and others, but not heretofore developed into a practical test. The preparation and use of this indicator are described in this issue of the JOURNAL (p. 427) by W. Allan Moore, whose work has been chiefly instrumental in developing it into a practical qualitative test, readily adaptable for field use. Moore has also completed the work of making the test roughly quantitative, having developed semi-permanent color standards similar to those used in the ortho-tolidine test.

In a considerable number of break-point chlorination experiments carried out during the past two months, in which chlorine and chloramine residuals have been checked throughout the break-point curve by means of ortho-tolidine and measured oxidation-reduction potentials in parallel, the dimethylaniline indicator has invariably shown the first appearance of free chlorine in concentrations as low as 0.1 ppm., coinciding with or immediately beyond the break-point. In a few nearby cities, where break-point chlorination of the public water supply has been in progress for some time, the indicator has shown free chlorine strongly at various points in the distribution system. Further field tests of this kind are being carried out in other water systems, where both simple and break-point chlorination are being practiced.

Results of Studies

The results of the study thus far may be summarized briefly as follows:

1. Concentrations of free chlorine as low as 0.05 ppm. are lethal to coliform bacteria within very short periods of time, and concentrations of 0.1–0.2 ppm. have been found to kill all of the exposed coliform bacteria within a period of about 2 min., at pH 6–7. This period is approximately doubled at pH 8 and trebled at pH 9. For chloramines, a similar effect due to pH variation was observed.

2. To accomplish the same degree of bactericidal action as that of free chlorine, the concentration of chloramines required with the same period of contact, or the necessary period of contact with the same concentration, appears to be about 20–30 times that which is necessary for free chlorine.

3. When ammonia is present in any amount in a chlorinated water, no free chlorine can remain in the water for long periods of time until the chlorine-ammonia reaction has been completed. At pH 7 or above, this reaction appears to be very rapid, but is retarded at lower pH values and probably also at low temperatures. Under these circumstances, free chlorine may be present for short periods immediately after chlorination and while present can exert its full bactericidal action.

4. The bactericidal effectiveness of sodium hypochlorite has been observed to be practically the same as that of chlorine, when added to water in equivalent amounts of HOCl. Characteristic break-point curves have been obtained with hypochlorite in the presence of free ammonia in the water treated, under controlled pH conditions.

5. A saturated acetone solution of *p*-aminodimethylaniline has been found to provide a delicate and specific colorimetric indicator for free chlorine in water in concentrations as low as 0.1 ppm., both in the presence and in the absence of chloramines. A sharp upturn in the measured oxidation-reduction potential also indicates the presence of free chlorine.

Conclusions

The practical implications of these results may be very briefly stated, though some of them at least will be evident to most students of water chlorination and its recent developments. Perhaps most important are: (1) the desirability of maintaining free chlorine residuals of 0.1–0.2 ppm. where rapid and effective bactericidal action is needed; (2) the desirability of chlorinating waters of any free ammonia content beyond the break-point whenever the high bactericidal power of free chlorine is required; and (3) the possibilities afforded by *p*-aminodimethylaniline as a qualitative or quantitative test for free chlorine under conditions requiring the maintenance of free chlorine residuals in water distribution systems.

In water supplies requiring adequate sanitary protection throughout their entire distribution systems, it is recommended that a minimum free chlorine residual not less than 0.2 ppm. be maintained in all vital parts of the system, regardless of the added amounts of chlorine necessary. In water supplies requiring only primary chlorination and subject to no possibility of secondary contamination, an ortho-tolidine residual, at the point of treatment, of not less than 0.6 ppm. if the contact period is at least 30 min., and of not less than 0.3 ppm. with a minimum contact period of about 60 min. may be sufficient for ordinary conditions. In cases of any secondary contamination of a water supply beyond the point of primary chlorination, however, these residuals probably would not be adequate for complete protection, because of the time element involved in their action.

Ammonia-induced break-point chlorination, if consistently followed so as to leave a stable free chlorine residual of not less than 0.2 ppm. throughout a distribution system, should afford an effective method of water chlorination. If the natural ammonia content of a

raw water is low, equally effective sanitary protection with greater economy of chlorine would appear to be obtainable without resorting to the artificial addition of ammonia. If chlorine-absorbing substances other than ammonia are present in a water, their chlorine demand in addition to that of the ammonia present would have to be satisfied before any free chlorine in stable form would be available for rapid bactericidal action. In some of the experiments undertaken at Cincinnati, the non-ammonia chlorine demand has been a material factor in the amount of added chlorine required.

Future Plans

In the experiments thus far carried out, the coliform strains exposed to chlorine and its derivatives have been in the form of suspensions made up from laboratory cultures. It is planned to repeat a number of the experiments using natural suspensions of sewage bacteria, to determine whether the presence of such bacteria imbedded in the suspended matters carried by sewage may affect materially the required times of exposure to small concentrations of chlorine. It is also intended to carry out further studies of chlorination along the following general lines: (1) comparative effects of free chlorine and chloramines on certain pathogenic bacteria of intestinal origin, as related to their effects on coliform strains; (2) effects of wider variations in pH and in water temperature on the bactericidal activity of chlorine and chloramines; (3) possibilities of controlling and maintaining free chlorine residuals in water distribution systems; and (4) further development of the *p*-aminodimethylaniline tests for quantitative as well as qualitative determination of free chlorine.

The experiments mentioned in connection with this brief preliminary report will be more fully described, together with their results, in subsequent papers by members of the staff of the Stream Pollution Investigations Laboratory at Cincinnati. In this connection, a paper is in preparation dealing with the results of an extensive series of experiments on the bactericidal effectiveness of water treatment by the excess-lime method. In the chlorination experiments, the staff of the Stream Pollution Investigations Laboratory is indebted to Wallace & Tiernan Co., Inc., for the loan of a Marks titrator cell and also acknowledges gratefully the interest and helpful advice of Assistant Technical Director A. E. Griffin of that firm's staff.

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Use of *p*-Aminodimethylaniline as an Indicator for Free Chlorine

By W. Allan Moore

ALTHOUGH the use of *p*-aminodimethylaniline as a test for residual chlorine has been known for a number of years (1–4), no attempt had been made to utilize it for the detection of free chlorine in the presence of chloramine, until such a test was developed in connection with the determination of the chlorination break-point in the laboratory of the U.S. Public Health Service Stream Pollution Investigations Station at Cincinnati. This test is based upon the fact that, above a pH of 6.0, chloramines decompose comparatively slowly. Therefore, on the addition of *p*-aminodimethylaniline to a sample above this pH value a "red flash color" is obtained when free chlorine is present. If free chlorine is absent, but chloramines are present, then on the addition of a few drops of 10-per cent H_3PO_4 the red color will appear due to the liberation of free chlorine from the chloramines at the lowered pH (4.0 or below). Even though *p*-aminodiethylaniline indicator may also be used, it is somewhat less sensitive than the dimethyl compound.

In the use of this indicator, several complicating factors must be kept in mind. If the pH is low (below 6.0) chloramines will give a false color and ferric iron (more than 0.1 ppm.) and manganic manganese will interfere. By buffering the pH of the sample to be tested at 6.0 * (or slightly above), interference from these sources is largely eliminated. With increasing pH value, however, dissolved oxygen becomes a more active oxidizing agent and will give a color equivalent to about 0.05 ppm. of free chlorine in approximately 3 min. Chloramines give no color at pH 6.0.

In using either of these indicators a saturated solution of the hydrochloride in acetone is made up and *kept in a brown bottle*. The stability of this solution is such that it may be used over a period of several weeks. To approximately 50 ml. of the solution to be tested is added 2 ml. of buffer solution (pH between 6.0 and 7.0) followed by 0.5 ml. of the indicator and if free chlorine is present the "red flash color" appears instantly. If no color is obtained the solution may then be tested for chloramines by the addition of three or four drops of 10-per cent H_3PO_4. The appearance of the red color denotes their presence. This lat-

A contribution by W. Allan Moore, Assoc. Chemist, U.S. Public Health Service Station of Stream Pollution Investigations, Cincinnati, Ohio.

* The use of Clark and Lubs phosphate buffer solution is recommended for this purpose.

ter reaction is somewhat slower than the free chlorine reaction.

If the pH of the water being tested is not lower than 6.0 or higher than 7.5 the buffer solution need not be added. The same precautions should be observed at low water temperatures as in the use of ortho-tolidine.

It has been impracticable thus far to place this reaction on a precisely quantitative basis, though it may be used as a semi-quantitative determination of free chlorine in the field. Standards have been made up using a mixture of basic fuchsin and copper acetate in varying proportions. These have shown no fading after five weeks. The solutions needed for preparation of the standards are:

1. Basic fuchsin stock solution containing 50 ppm. (50 mg./l.)
2. Basic fuchsin solution for standards (This is made up by diluting 25 ml. of the stock solution to 500 ml. with distilled water.)
3. Copper acetate standard solution 0.1*M*. (This is made up by dissolving 19.96 g. of copper acetate ($Cu(C_2H_3O_2)_2H_2O$) in 1 l. of distilled water.)

The standards are made up in 50-ml. short-form Nessler tubes with varying proportions of basic fuchsin and copper acetate. The proportions will vary, depending upon the type of tube used, for which reason the standards are best prepared from carefully standardized solutions of free chlorine. In making up the standard chlorine solutions, chlorine demand-free water must be used for all dilutions.

Standards for the determination of free chlorine in the field were made up by using the following proportions of basic fuchsin and copper acetate:

Chlorine, ppm.	*Basic Fuchsin, ml.*	*Copper Acetate, ml.*
0.05	2.2	0.7
0.10	3.5	1.0
0.20	7.0	1.8
0.30	13.5	2.6
0.40	17.0	2.6

A 0.5-ppm. standard was not made up due to the fact that above 0.4 ppm. the color developed between free chlorine and *p*-aminodimethylaniline is of a different shade than any combination of basic fuchsin and copper acetate that could be found. If free chlorine concentrations are encountered above 0.4 ppm., a smaller amount of sample should be used and diluted with distilled water. As mentioned previously, the proportions as given in the above tabulation may have to be varied, depending upon the kind of tubes used and type of glass of which they are constructed.

Although the study of this procedure is to be continued in the field at communities where break-point chlorination is being used, the procedure is being published at this time to stimulate its wider trial for the control of break-point chlorination.

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Adjudication of Water Rights in the Raymond Basin

By C. W. Sopp

A NUMBER of unique features regarding the Raymond Basin water rights adjudication make its study interesting to water works men throughout the country. Such factors as the number and character of parties involved, the appointment of the State Division of Water Resources as referee, the character of water rights, the points of law involved and the physical and legal features of the proposed solution and settlement are discussed here. The additional feature, that of an overdrawn ground-water basin, is not unique in Southern California, nor is it in many other parts of the country, particularly during the present emergency period.

Raymond Basin

The Raymond Basin lies in the northwesterly portion of the San Gabriel Valley of Southern California (Fig. 1). It underlies the communities of Pasadena, Altadena, Sierra Madre and intervening unincorporated territory. The surficial area is 24,000 acres, whereas the area of the underlying water basin is about 20,000 acres. The basin is bounded on the westerly, northerly and easterly sides by granitic foothills and mountains, but the boundary on the southerly side is a fault in alluvium. The movement along the fault line caused folding, offsetting of aquifers and the formation of gouge which have created an almost impermeable ground-water dam.

The basin was formed by the subsidence and rotation of the bedrock block between the Raymond fault, forming the southerly boundary, and the fault at the foot of the mountains. The depression thus created has been filled with detritus eroded from the mountains and deposited where the streams debouch upon the mesa. The Arroyo Seco and Eaton Canyons are the principal mountain tributaries and the alluvial fans of these streams have dominated the alluvial fill. The washes of these streams extend entirely across the basin and the alluvium deposited by them is more porous than the fans of the smaller intervening streams, whose washes terminate within the basin. A well has been drilled to a depth of 1220 ft., the bottom being over 400 ft. below sea-level, without reaching the bedrock floor of the basin.

Geological studies augmented by geophysical surveys have been made of the ground-water basin. Two seismic geophysical surveys determined the depth to the water table and bed-

A paper presented on October 29, 1942, at the California Section Meeting, Oakland, Calif., by C. W. Sopp, Asst. Chief Engr. & Gen. Mgr., Pasadena Water Dept., Pasadena, Calif.

rock in local areas. Dynamite was exploded and the interval of time between the explosions and the arrival of the refraction waves from the water table and bedrock were measured by seismometers. From these data, calculations of the depths were obtained. Electrical resistivity surveys were also made to determine the depth to water table. From these surveys and data obtained from wells drilled to bedrock the approximate configuration of the

The alluvial fill was classified into recent, old and ancient alluvium. The ground water principally occurs in the older alluvium which is semi-decomposed and consolidated. The average specific yield of the alluvium is 10 per cent.

The surface of the water table has a distinctive configuration throughout the basin (Fig. 3). In the northwesterly portion, the water table is comparatively flat; it then descends

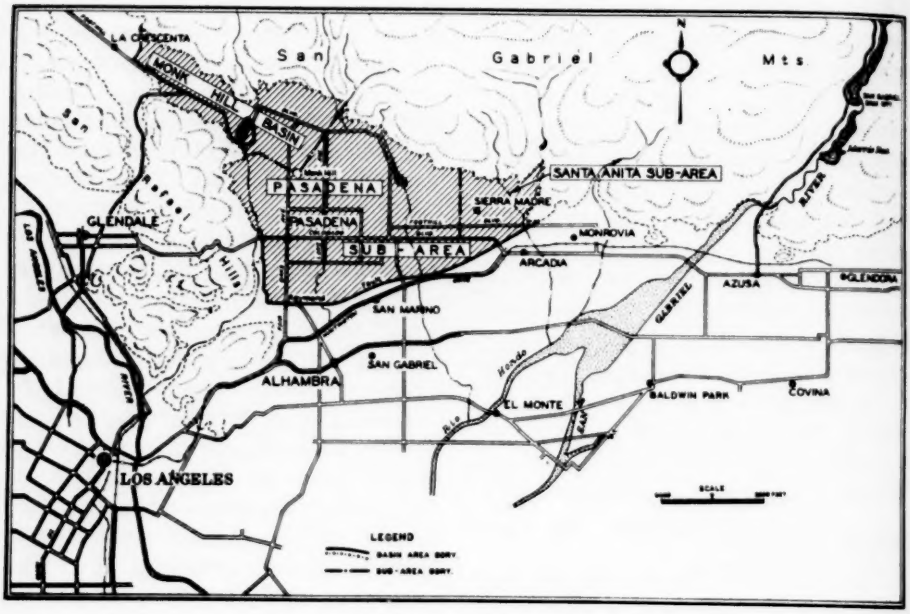

FIG. 1. Key to Raymond Basin Area

bedrock basement complex was obtained over a large portion of the area. Figure 2 shows the geology of the area.

The topography of the bedrock revealed a deep gorge in the bedrock, where, previously, a ridge, forming a ground-water barrier, had been postulated. It revealed a buried canyon of the Arroyo Seco which departed from the present course, showing that it was formerly tributary to another stream system.

through an elevation of about 250 ft. through an alluvial-filled bedrock gorge to the central portion, where it is again relatively flat. Easterly from this central portion, the water table has a slope of 80 ft. to a flat area in the easterly portion of the basin. The depth to the water table in the upper portion of the basin is 100 ft., in the central portion, 350 ft., and in the lower portion, about 100 ft. The water table in the basin northerly of

the Raymond fault generally stands about 300 ft. higher than that in the San Gabriel Valley, immediately southeasterly of the fault.

Water Rights Suit

From studies of the hydrology of the basin, the City of Pasadena had long known that the aggregate draft upon the ground-water basin exceeded the average supply or safe yield. This was evidenced by the large recession of the water table. The city could not however, bring a suit to limit the draft on the basin until it had obtained a supplemental water supply, as its draft would be curtailed as well as that of all other pumpers. Prior to the filing of the suit, a number of meetings were held with representatives of the principal parties taking water from the ground-water basin in an effort to reach an agreement outside of court, preserving the storage in the ground-water basin. These meetings were ineffective, there being no compelling action, so a suit was filed in September 1937. The purpose was to quiet title to the city's ground-water rights and to limit the total draft on the Raymond Basin to the safe yield. A number of hearings were held before the court on demurrers. Attorneys for the defendants argued that all parties pumping water from the basin should be joined in the suit. The court ruled, that such joining of all parties was unnecessary, but did require the city to amend its complaint, making defendants of all entities pumping more than 100 acre-ft. annually. The court also ruled that it was not a simple quiet title suit, but was a general adjudication of the water rights in the basin. All answers were to be interpreted as cross-complaints, each against the other. The city's complaint was limited to ground-water rights, but many of the defendants argued that surface diversion from tributary mountain streams should also be made subject to the litigation.

There are 30 defendants consisting of municipalities, mutual water companies, an irrigation district, a county water district, public utilities, industries and individuals. Figure 4 shows the areas served by the parties to the suit. The classes of water rights involved are those of appropriators, municipalities and mutual water companies, overlying land owners who had put water to beneficial use and overlying land owners who had not put water to beneficial use.

Some of the points of water law involved may be summarized as follows:

1. Are the tributary streams and ground-water basin to be considered one water field?

2. Does the ground water exist as a stream in well defined channels or as percolating water?

3. How should appropriative rights in an overdrawn basin be determined; that is, from production down to the date of the suit or to the date the basin first became overdrawn?

4. In an overdrawn basin, have appropriators perfected rights against an overlying landowners who has not exercised his rights?

5. Are the rights of mutual water companies to be considered as overlying landowner rights?

6. What is the effect of the intervention of public use?

If the case goes to trial new points of law involving water rights will be determined.

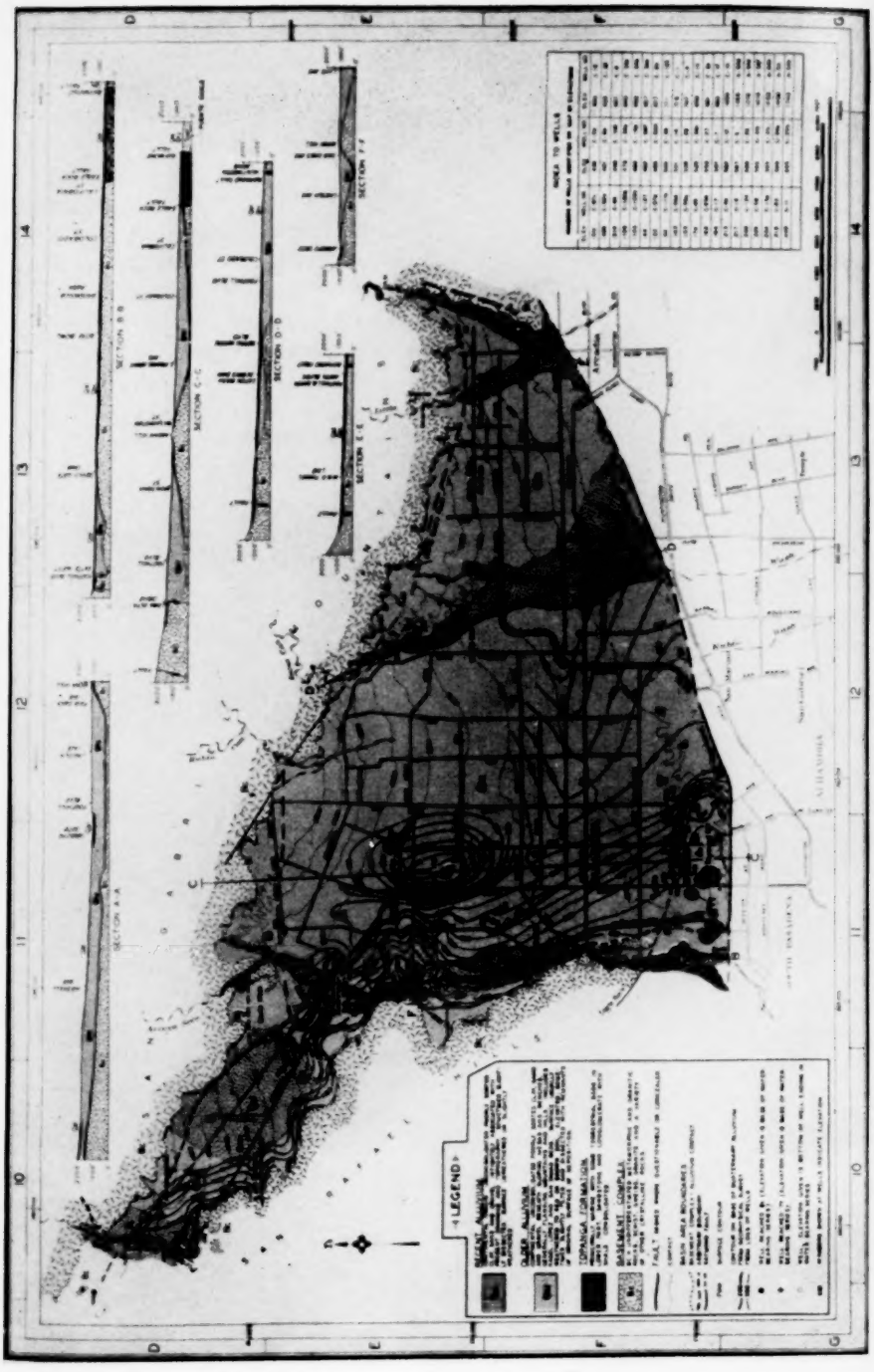

FIG. 2. Areal Geology of Base of Quaternary Alluvium

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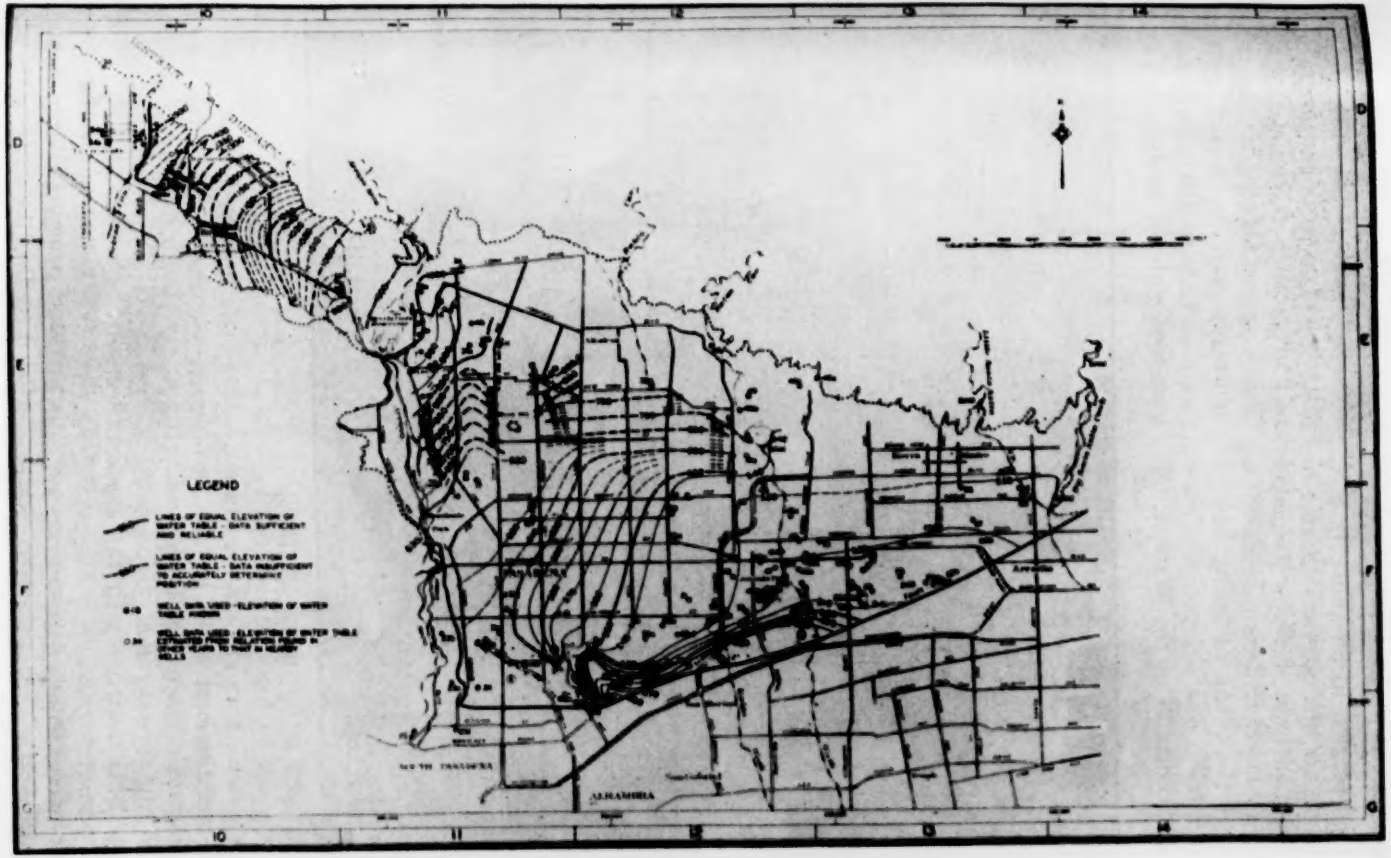

FIG. 3. Contours of Water Table, Spring, 1937

Appointment of Referee

Upon petition to the court by most of the parties, the case was referred to the State Division of Water Resources to act as referee to determine all of the physical facts, but excluding conclusions of law. The reference was made under Section 24 of the Water Commission Act. Harold Conkling, Deputy State Engineer and Chief of the Division of Water Resources, conducted the investigation assisted by George B. Gleason and a staff of engineers and geologists.

The referee's study required two and one-half years. On numerous occasions, the referee called conferences with consultants of the parties for consideration of his work in order to eliminate all possible exception that might be filed against his report. The referee informally filed his report with the parties in October 1941, but it has not been filed with the court.

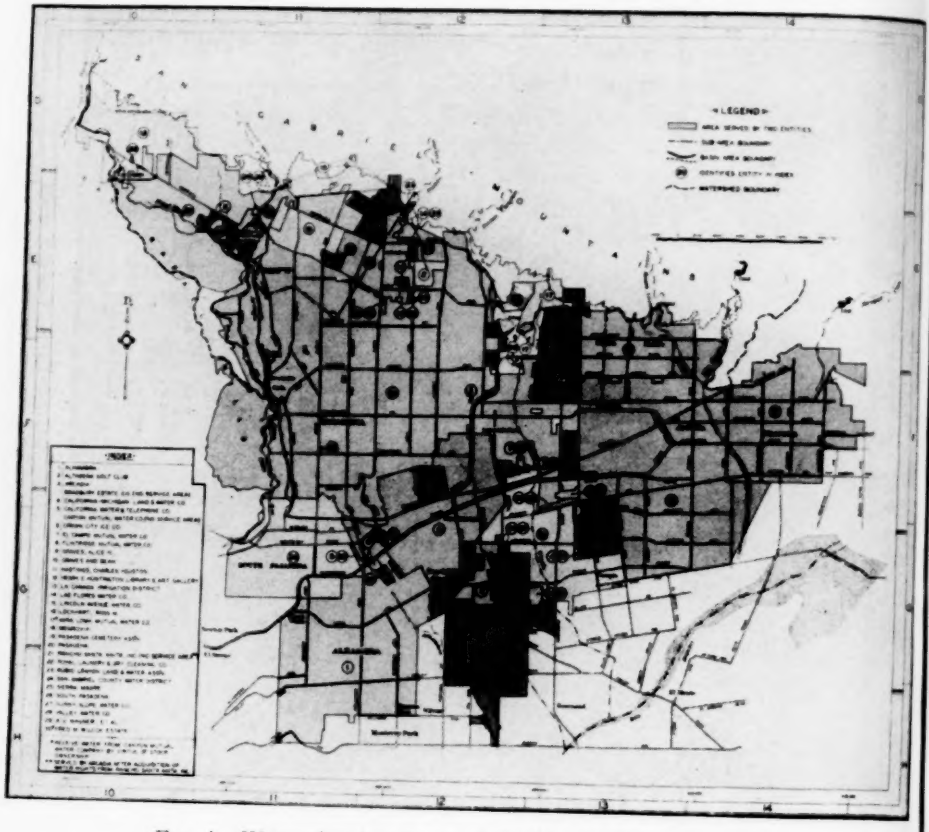

FIG. 4. Water Service Areas of Entities in Suit, June 1941

The referee's study cost approximately $50,000. A portion of the cost was assessed upon the basis of a uniform charge to all parties and the remainder distributed in accordance with the average pumping during a given period preceding the filing of the suit.

Water Supply

The supply to the ground water was computed by the equation: draft plus or minus change in ground-water storage equals the safe yield. For example, if, over a period of years, the average draft on the ground water was 20,000 acre-ft. and the storage was reduced 5000 acre-ft. annually, the safe yield would be the difference or 15,000 acre-ft.; and, conversely, if the storage increased 5000 acre-ft. the safe yield would be the sum of the draft and increase, or 25,000 acre-ft. The actual draft in comparison to the safe yield gave the overdraft or surplus.

A study was made by the referee over an 11-yr. period of nearly normal water supply conditions. Additional studies were required to adjust the 11-yr. safe yield to a long-time average period, to compute the ground-water outflow or basin leakage, and to estimate the ultimate safe yield. This required a study of the gross supply or the difference between the water entering the basin and water leaving, *i.e.*, losses.

The water entering the basin is runoff from the adjoining mountains and foothills and rainfall on the surface of the basin. The water leaving the basin is storm runoff, sewage and evaporation and transpiration losses.

The study of long-time rainfall and runoff records indicated that the 29-yr. period from 1904–05 to 1932–33 was of about normal climatic regimen. Computation and estimates were made of the differences in water entering and leaving the basin for this 29-yr. normal period and that of the 11-yr. period. The 11-yr. safe yield was corrected to the 29-yr. normal to obtain the average supply. The gross supply minus the safe yield gave values for underground outflow or leakage.

The study involved compilation of voluminous rainfall and runoff records, measurements of the depth to water table in wells and ground-water draft. The pumping by many parties was unmeasured and required estimates to be made either from areas served and duty of water, or from power consumption and efficiency test of pumping plants. The study also required a detailed survey of the culture overlying the basin, such as lawns, ornamental shrubbery, orchards, garden produce and vacant areas. Many soil moisture tests were made on typical areas and studies of metered water application were made to determine the duty of water and the consumptive use or evaporation and transpiration losses for typical classes of culture. These surveys of losses were applied to the cultural survey to give the amount of water lost to atmosphere. The following tabulation gives the duty of water for various culture classifications:

Classification	*Acre-ft./Acre*
Estates	1.93
Residential, Class A	1.94
Residential, Class B	1.53
Residential, Rural	1.01
Schools	1.49
Parks	3.00
Lawns and Ornamental Shrubs	2.17
Commercial (to 3 stories)	3.74

The study also involved determination of the specific yield of the alluvium, when drained, to take into consideration the changes in amount of water in ground-water storage within the basin.

The referee determined that the Raymond Basin, for all practical purposes, was divided into the Western

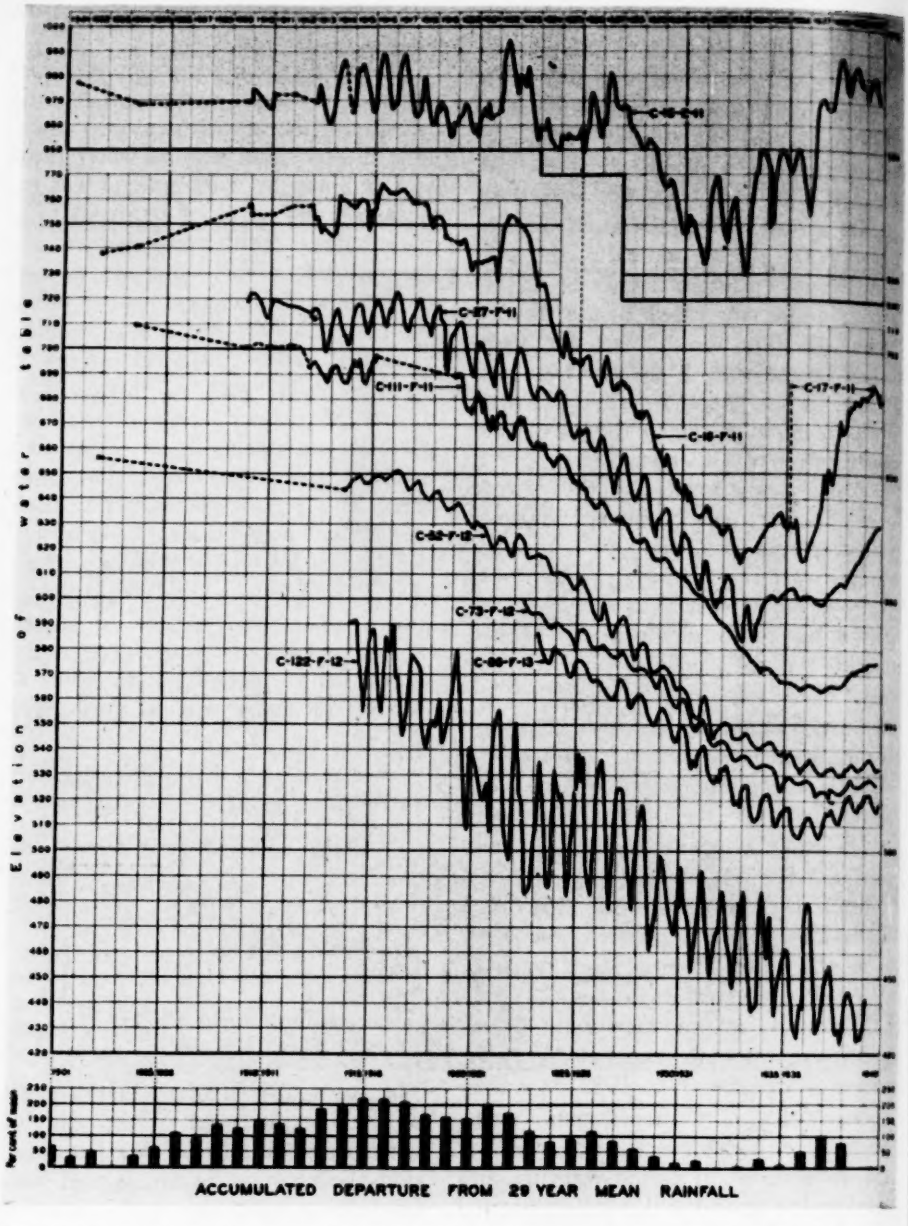

FIG. 5. Fluctuations of Water Table at Wells on Main Arroyo Seco Ground Water Stream

Unit and the Eastern Unit. He computed the present safe yield of the Western Unit to be approximately 18,000 acre-ft., with an annual outflow or leakage through the Raymond fault of 2900 acre-ft., and the safe yield of the Eastern Unit to be 3800 acre-ft. with an annual outflow of 600 acre-ft.

The engineering staff and consultants of the Pasadena Water Department made a parallel independent study of the water supply and substantially confirmed the findings of the referee. Samuel B. Morris and A. L. Sonderegger are the city's consultants.

Draft and Overdraft

The total draft on the Western Unit exceeded the safe yield, or average annual supply, from 1914–15 to 1934–35 when the city reduced its pumping, having secured a supplemental supply. During this period the excess of draft over safe yield, or overdraft, totaled 134,000 acre-ft. This overdraft would, under ordinary circumstances, have caused a recession of the water table of 75 ft., but combined with a succession of dry years there was actually a recession of 145 ft. in certain localities, as shown in Fig. 5. It was only through draft on the large volume of ground-water storage that this overdraft was possible. In Fig. 5, the fluctuation of the water table, as shown by Well C-10, is typical of the Monk Hill Basin, a subdivision of the Raymond Basin; the fluctuation of all other wells, except C-122, is typical of the central portion of the Raymond Basin, while that of Well C-122 represents fluctuations above the Raymond fault in a former artesian area.

The overdraft on the Western Unit has, in recent years, averaged 9000 acre-ft. annually. A reduction in pumping of about 31 per cent is required to limit the total draft to the safe yield and to prevent further permanent lowering of the water table. The reduction will require new outside supplies of about 5000 acre-ft. annually for the city and 4000 acre-ft. annually for the defendants.

The safe yield of the Eastern Unit exceeds the draft; therefore, at present, there is a surplus in this unit. The unit is relatively small, however, and only two parties to the suit pump water from it.

Settlement

The referee has not formally filed his report with the court, giving time for the parties to attempt to work out a settlement. A committee of seven, consisting of attorneys and engineers, was appointed to study ways and means of settling the suit outside of court, thereby reducing court costs. After months of study, the committee presented its report to the parties, most of whom informally expressed their willingness to settle on the basis proposed. Such settlement would be in the form of a stipulated judgment.

The general principles of the basis of settlement are to define the rights of all parties to the suit and the reduction of all rights proportionately to the safe yield of the basin, thus accomplishing the purposes of the suit. The committee's report also proposes a means whereby those parties having a deficient supply can obtain a supplemental supply, at least for a period of time, from those parties having a surplus available from outside the basin. Certain of the parties have wells outside the Raymond Basin; and the City of Pasadena has a supplemental supply from the Colorado River, being a member of the Metropolitan Water District. These parties having an auxiliary sur-

plus supply will draw upon these sources and take less water than their decreed rights from the Raymond Basin, thus making release water available to parties having a deficient supply. The detailed provisions of the proposed settlement are:

1. Gravity diversions from the mountain streams entering the basin shall be fixed as of their maximum capacity.

2. All rights to take water from the ground-water basin are of the same priority and mutually prescriptive.

3. A finding shall be made of present rights of all parties.

4. The decreed rights of all parties shall be their present rights reduced proportionately such that the total of all decreed rights shall equal the safe yield of the basin less the draft of non-parties.

5. Provision shall be made that any party may extract 120 per cent of its annual right in any year but in any five-year period shall not exceed five times its decreed annual right.

6. Provision shall be made for determination of any change in safe yield.

7. Provision shall be made for parties having a deficient supply to request annually on May 1 the amount of water they require.

8. Similarly, on May 1, all parties having a surplus shall offer to release the amount of this surplus and state the offering price.

9. The report sets a ceiling price which can be requested by the parties having the surplus, this ceiling price being in general the average annual cost of production.

10. The report provides for the appointment of a water master by the court for the enforcement of the decree and operation of the agreement.

11. The water master, taking into consideration the amounts requested, the amounts offered and the lowest prices of the offered water, is to allocate the furnishing of the released water equal to the surplus of those parties offering it at the lowest prices.

12. All parties taking surplus water thus made available are to pay the same price through a release pool beginning with the lowest priced water.

13. Payment for taking of released surplus water shall be made to the water master who shall in turn pay the parties releasing water.

14. The report provides for the appointment of a board representing the parties to act in an advisory capacity to the water master.

15. A requirement is made that all parties make records of water levels and quantity of water pumped.

Conclusion

If the settlement is accomplished, the overdraft will be stopped and the purposes of the suit will be obtained outside of court, thus avoiding the long and costly water rights litigation. The total pumping from the basin will be limited to the safe yield and, over a long period of time, the water table will fluctuate above and below a mean elevation, rising during a wet series of years and receding during a dry series of years. This unique feature of limitation of the draft to the safe yield and the legal and physical means of settlement may be applicable to other overdrawn ground-water basins in California.

Use of Turbidity Determinations in Estimating the Suspended Load of Natural Streams

By Richard G. Grassy

DETERMINATION of the quantity of sediment transported in suspension by streams is a problem of much importance in the design of reservoirs, canals, navigation projects, hydroelectric plants and water works systems. A reliable determination of the average annual and seasonal suspended load transported past a given point on a stream has been possible in the past only if records covering a considerable period were available. Such records were based on calculations involving the stream discharge and what is termed "concentration" of suspended sediment, usually expressed in parts per million by weight, i.e:

$$\text{Concn., ppm.} = \frac{\text{Dry wt. of suspended matter}}{\text{Wt. of mixt. of suspended matter and water}} \times 10^6$$

Sometimes the volume instead of the weight of mixture was used, but such records were less reliable.

In such determinations, the longer the record available, the more reliable is the estimate. Unfortunately, however, few extensive suspended-load records exist. In the United States, suspended-load sampling has been conducted for more than five years at only a very few stations, most of them on large streams. At several thousand locations throughout the country, the turbidity of river water has been recorded, sometimes for half a century or longer. In 1876, George Hornung (1) was measuring the turbidity of the Ohio River at Newport, Ky. The Jackson turbidimeter (2), which has been used widely in such work, was introduced in about 1900.

Since the turbidity of a water sample is known to be related to the concentration of suspended sediment, the measurements described in this paper were undertaken as a preliminary investigation of two problems:

1. Under what conditions may old turbidity records be utilized in deriving estimates of suspended load?

2. To what extent may turbidity measurements be employed in reducing the cost of present suspended-load investigations?

Turbidity is not synonymous with concentration. The word turbid, as pointed out by Wells (3), is derived from the Latin verb *turbare,* "to disturb." Thus a turbid medium is one in which the mud or suspended matter has been stirred up, or, in scientific usage, a "medium containing small

A contribution by Richard G. Grassy, formerly Asst. Geologist, Sedimentation Div., Soil Conservation Service, U.S. Dept. of Agriculture, Greenville, S.C., now Assoc. Geologist, U.S. Engr. Office, Jacksonville, Fla.

particles in suspension" is turbid. The suspension of these small particles has a marked effect on the appearance of the medium.

To compare the appearance of turbid mediums, some means of expressing turbidity must be employed. Early methods of expressing turbidity made use of descriptive terms such as "very slight," "slight," "distinct" and "decided." Hornung expressed turbidity as the reciprocal of the depth of water, in inches, at which the image at the end of his diaphanometer disappeared. Similarly, the scale at first used with the platinum wire method gave a turbidity of 1.0 when the depth at which the wire disappeared was 1 in., 0.5 when the depth was 2 in., etc. Objections were raised to the reciprocal scale as not connoting the amount of turbidity-producing matter in the water. With the adoption of the turbidity standard of 1902 (4) and the introduction of standard suspensions (5, 6, 7), turbidity measurements were connected definitely with amount of suspended matter. Since that time most turbidimeters have been calibrated by means of standard silica suspensions, the turbidity of a water sample being expressed as the concentration of a standard silica suspension possessing an equivalent turbidity.

The suspended matter in natural streams is not pure silica, but consists of a mixture of mineral grains of different composition, refractive index, color and particle size, often associated with considerable organic matter. Therefore, although turbidities of water samples are now generally expressed in parts, per million, this figure does not necessarily indicate the actual concentration of suspended matter in the water sample, but indicates only that a standard silica suspension of this concentration would produce the same optical effect as the water sample with respect to transmitted or reflected light. This is made clear by a theoretical consideration of turbidity.

As Wells (3) has shown, the optics of turbid media are very complicated; and the brightness of a turbid medium is by no means a simple function of the concentration of the dispersed phase. For particles of one substance and one size, small in comparison with the wave length of light, he derived from Rayleigh's expression (8) the following relation for the brightness, B, of a thin section of a turbid medium:

$$\frac{B}{B_0} = \frac{Kd^3Cx}{\lambda^4}$$

where B_0 is the brightness of a comparison field illuminated by the same source; C, the concentration; d, the uniform diameter of the particles; x, the thickness of the section in the direction viewed; λ, the wave length of light employed; and K, a constant. For particles larger than the wave length of light, the brightness is expected to be proportional to the total surface of the particles and to be dependent on the color of the light only as the reflection coefficient varies with λ. Then:

$$\frac{B}{B_0} = \frac{KCx}{d}$$

Since particles of many different sizes are found in ordinary suspensions, the relations become much more complex. The effect of secondary scattering and reflection, and of absorption, are ignored in the above expressions. Where different substances are involved, different refractive indices must be introduced. It is thus evident that the

brightness of a turbid medium can be taken as a direct measure of concentration only in very special cases.

Description of Investigation

Conclusions reached in this paper are based on 654 pairs of water samples taken during the year 1940 from the Enoree River at the sediment-load laboratory of the Sedimentation Division, Soil Conservation Service, near Greenville, S.C. (9). The Enoree River is a typical stream of the Southern Piedmont, rising at the foot of the Blue Ridge Mountains. Above the sampling station, the river has a drainage area of 64.4 sq.mi. Many streams of similar character are utilized as a source of water supply. In fact, the Enoree formerly furnished the water supply of Greenville, S.C.

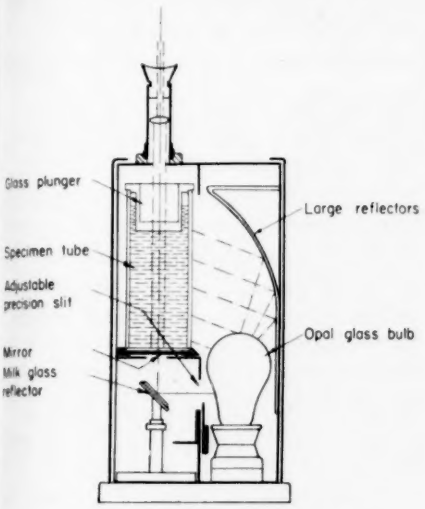

FIG. 1. Diagrammatic Sketch of Turbidimeter

Samples were taken in pairs, always at the same point in a cross-section of the Enoree River at the control station. One sample was used for determination of turbidity and the other for the gravimetric determination of suspended matter. Suspended matter was determined by filtering, drying and weighing. Alundum filter crucibles were used. Residues and crucibles were dried at 105° to 110°C. until weight was constant within 0.5 mg. for each determination. The concentration of suspended matter was calculated as follows:

$$\text{Concn. ppm.} = \frac{\text{Dry wt. of suspended matter, g.}}{\text{Wt. of mixt. of suspended matter and water, g.}} \times 10^6$$

A Hellige turbidimeter No. 8000-A (Fig. 1) was used to measure turbidity (10). Light rays from the opal glass bulb of this instrument are reflected into the liquid column in the tube, a Tyndall effect being produced by this illumination of the suspended particles. Light rays from the bulb likewise pass through the slit and are reflected through a circular aperture in the mirror and thence through the liquid in the specimen tube into the ocular. These rays appear as a circular spot in the center of the Tyndall effect of the illuminated liquid, the spot being brighter or darker than the Tyndall light, depending on the size of the opening of the slit. By revolving a graduated drum and thereby adjusting the opening of the slit, the brightness of the spot can be regulated so as to be of the same intensity as the brightness of the surrounding field. The position of the drum is then read. The turbidity, in parts per million of silica, corresponding to this reading is taken from a calibration curve supplied with the instrument.

The standard procedure adopted for the turbidity determinations was as follows: The water sample was dispersed in an electric drink mixer for five minutes after which a portion was quickly transferred to the specimen tube of the

turbidimeter. Two successive instrument readings were taken as rapidly as possible. The specimen tube was then emptied and cleaned, the water sample again dispersed and the process repeated. The arithmetic mean of the four drum readings was used to obtain the turbidity from the calibration curve of the instrument.

The maximum turbidity that could be measured directly with this instrument was equivalent to approximately 100 ppm. of suspended matter. In fact, readings on samples with concentration of suspended matter greater than 60 ppm. were difficult to reproduce. Best results were obtained on concentrations of less than 50 ppm. Turbidities beyond the range of the instrument were measured by diluting the water samples with distilled water until the concentration was sufficiently reduced to permit accurate readings. The turbidity of the original sample was calculated by the relation:

$$T_0 = \frac{V_D}{V_0} \cdot T_D$$

where T_0 = turbidity of original sample, V_0 = volume of original sample, V_D = volume of sample after dilution and T_D = turbidity of diluted sample.

To test the reliability of the dilution method, several samples of known concentration were diluted by known amounts in successive steps, the turbidity being measured for each dilution. The data for one of these dilution tests are shown in Table 1. The tests showed no systematic change in coefficient of fineness (11)

$$\left[\text{coef. of fineness} = \frac{\text{suspended matter, ppm.}}{\text{turbidity, ppm. of silica}}\right]$$

with increasing dilution and verified the validity of the method for obtaining turbidities beyond the range of the instrument. Since it was found that instrument readings falling within the range of 20 to 30 units of the graduated drum were most easily duplicated, an attempt was made to bring all samples within this range by diluting. The maximum dilution used was equal to 25 times the original volume.

TABLE 1

*Results of Dilution Tests on a River-Water Sample Possessing an Original Turbidity Too Great to Permit Direct Measurement With the Turbidimeter**

$\frac{V_D}{V_0}$	Suspended Matter in Diluted Sample	Average Turbidimeter Reading	T_D	Coefficient of Fineness	$\frac{V_D}{V_0} \cdot T_D$
	ppm.				
6.00	73.0	43.25	92.0	0.79	552
7.02	62.3	41.75	87.5	.71	614
8.35	52.5	38.50	78.5	.67	655
10.10	43.4	34.00	66.0	.66	667
13.03	33.6	28.00	50.0	.67	652
18.24	24.0	23.00	37.5	.64	684
30.83	14.2	16.00	21.5	.66	663
92.49	4.7	8.25	6.0	.78	555
369.04	1.2	6.00	2.0	.60	738

* Sample taken on December 19, 1940, at 7:47 A.M. Concentration of suspended matter by gravimetric method = 435 ppm.

Whenever practical, simple multiples of the original volume were used.

Because a few large particles contribute practically nothing to the turbidity of a suspension of relatively fine particles, it was deemed advisable to exclude coarse sediment when comparing turbidities with suspended-matter concentration. An arbitrary division at a particle size of 0.061 mm. (250-mesh sieve) was chosen. For flood stages, turbidities were compared only with the concentration of sus-

pended matter finer than 0.061 mm. For normal stages, turbidities were compared with total concentration of suspended matter, sediment coarser than 0.061 mm. being negligible for these discharges. Normal discharges were below 100 cfs. Other investigations (12) of the sediment load of the Enoree River indicated that suspended particles less than 0.061 mm. in diameter were uniformly distributed throughout the particular stream cross-section at which sampling was conducted. This made it possible to base the suspended-load calculations on the results of sampling at a single point.

Results of Investigation

In Fig. 2, concentrations of suspended matter determined gravimetrically have been plotted against turbidities for all samples taken during 1940. The great variation in turbidity for the same concentration of suspended matter is at once evident.

The elimination of those samples having a pronounced artificial color does not effect a great improvement. This color was due to pollution of the stream by industrial wastes and dyes. The sedimentary particles, as well as the water, occasionally acquired considerable color from these waste products. To test the possibility that dissolved matter might influence the turbidity by altering the optical properties of the water and by acting either as a peptizer or a coagulant, total dissolved solids and specific conductance were determined on water samples taken simultaneously with many of the samples for turbidity determination. Total dissolved solids ranged from 30 to 154 ppm. (determined by evaporation and drying at 105° to 110°C. to constant weight and specific conductance varied between 3.4 and 18 ($K \times 10^5$ at 25°C.). Coefficient of fineness showed no relation to either concentration of dissolved solids or specific conductance.

Isolation of the coefficients of fineness for normal stages from those of flood stages revealed several interesting features. In Fig. 3, daily determinations of the coefficient for normal stages throughout the entire year have been plotted. Samples having pronounced artificial color and those connected with flood stages are not included. The coefficients show considerable random fluctuation within well-defined limits. In Fig. 4, the mean monthly coefficients of fineness for normal stages are shown together with the monthly rainfall. No relation between rainfall and coefficient of fineness for normal stages is evident. The relatively low coefficients for the last four months of the year are striking, but the record is considered to be of insufficient length to permit drawing conclusions for seasonal variations.

Detailed study of the changes in coefficient of fineness during individual floods showed that, although the coefficient might vary widely, the variations were not random. On the contrary, the changes followed a definite pattern. The following observations were made:

1. Major changes in suspended-matter concentration were reflected in turbidity.

2. Changes in the trend of the coefficient of fineness occurred where the trend of turbidity changed.

3. The coefficient of fineness reached a maximum early in the rising stages of a flood; this maximum was followed by a sharp decrease, after which the coefficient fluctuated but little, although dropping steadily for the remainder of the flood.

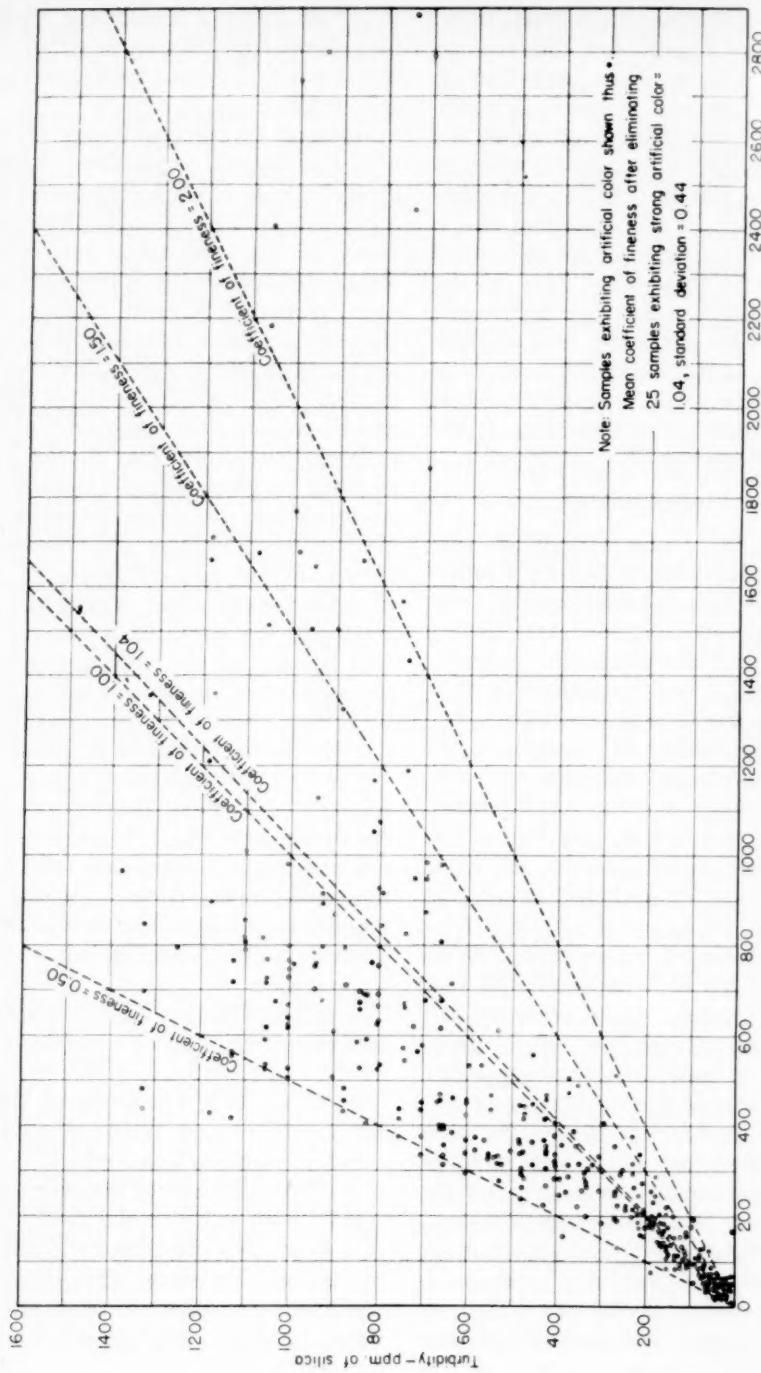
Turbidity—ppm. of silica
Suspended matter—ppm.
Coefficient of fineness = 2.00
Coefficient of fineness = 1.50
Coefficient of fineness = 1.04
Coefficient of fineness = 1.00
Coefficient of fineness = 0.50
Note: Samples exhibiting artificial color shown thus •.
Mean coefficient of fineness after eliminating
25 samples exhibiting strong artificial color =
1.04, standard deviation = 0.44

FIG. 2. Comparison of Turbidity and Suspended Matter of Enoree River for 1940

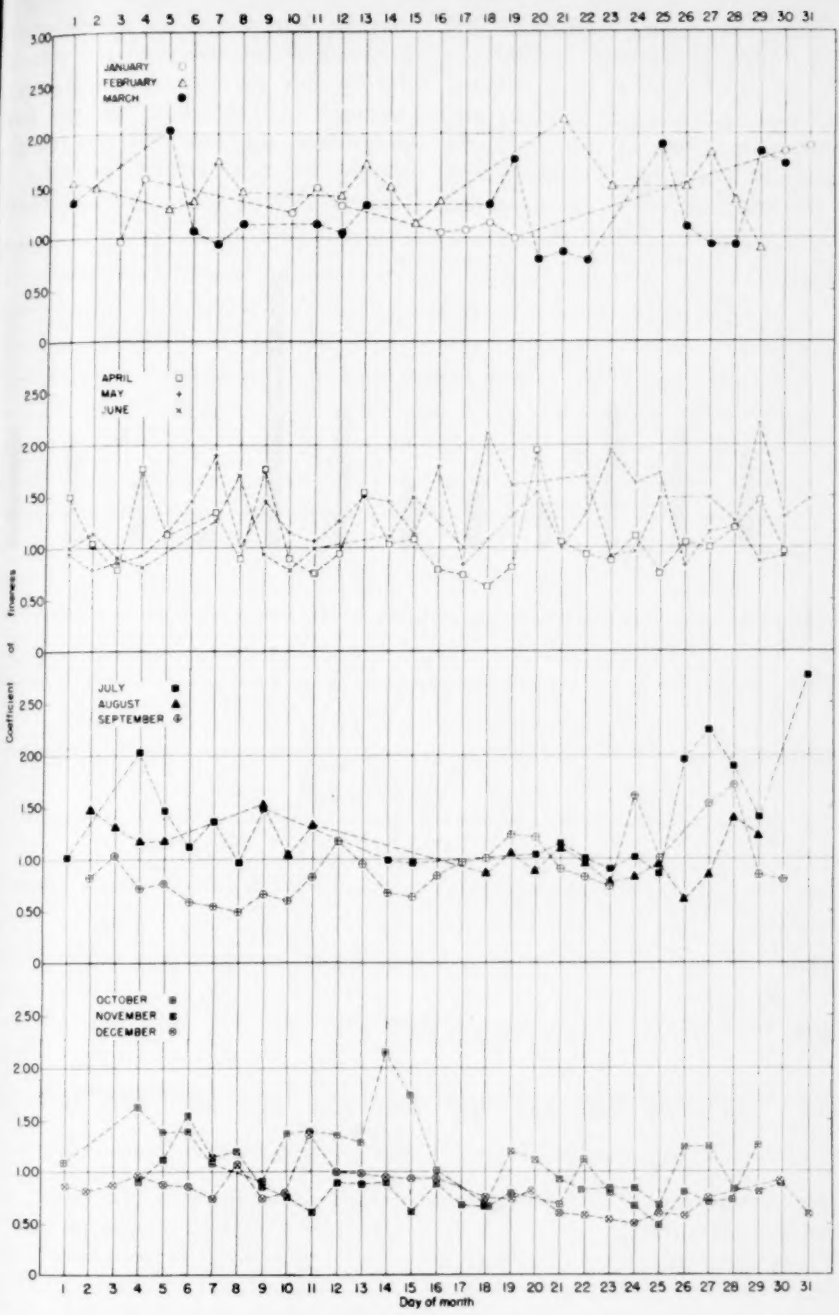

FIG. 2. Comparison of Turbidity and Suspended Matter of Enoree River for 1940

FIG. 3. Daily Variation in Coefficient of Fineness for Normal Stages (Samples exhibiting artificial color omitted)

4. The maximum coefficient occurred during those early periods in which the concentration of suspended matter was increasing at a high rate. Secondary increases in the coefficient occasionally occurred in conjunction with secondary increases in suspended matter concentration, but the general trend was not altered.

These observations are illustrated by Figs. 5 and 6, which give detailed records for two typical floods.

The high fineness coefficients observed in the early stages of each flood may be interpreted as indicating the presence of relatively coarse material during this period, while the steady decrease in coefficient, as the flood progresses, suggests that the available supply of this coarse sediment is limited. Investigations of soil loss on small agricultural plots have shown that, for a constant slope, the main factors governing erosion are rainfall intensity, rainfall duration, initial moisture content of the soil and condition of the soil surface (13, 14). Rainfall intensity is considered most important.

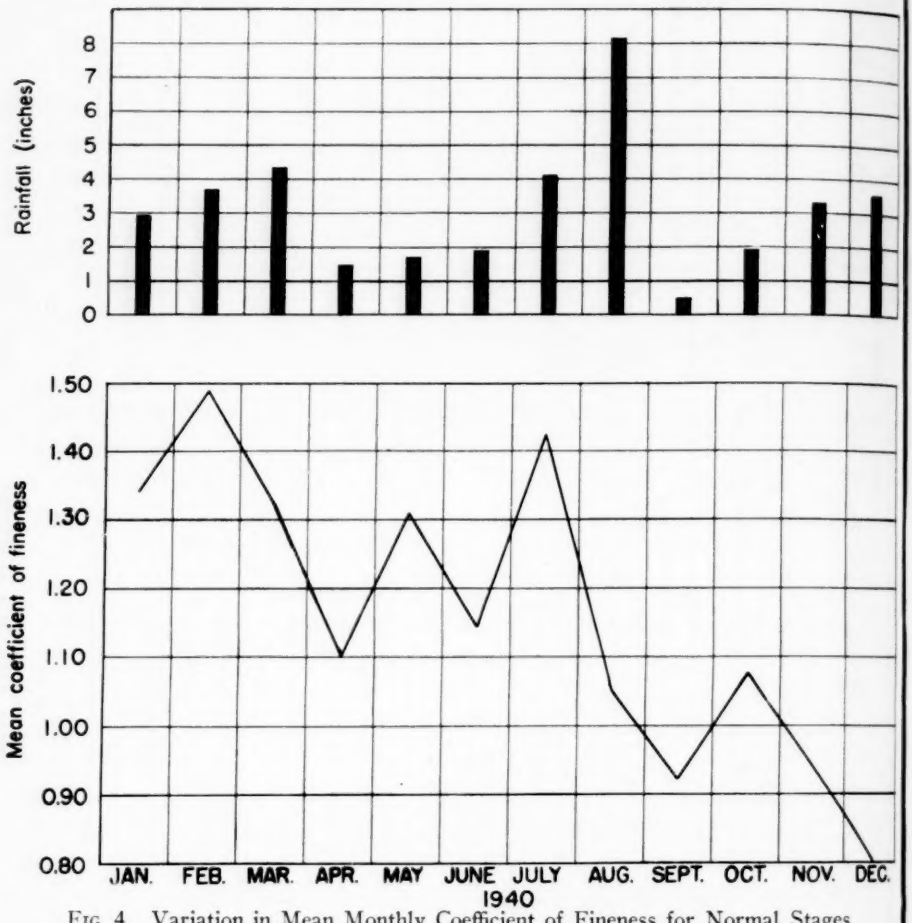

FIG. 4. Variation in Mean Monthly Coefficient of Fineness for Normal Stages

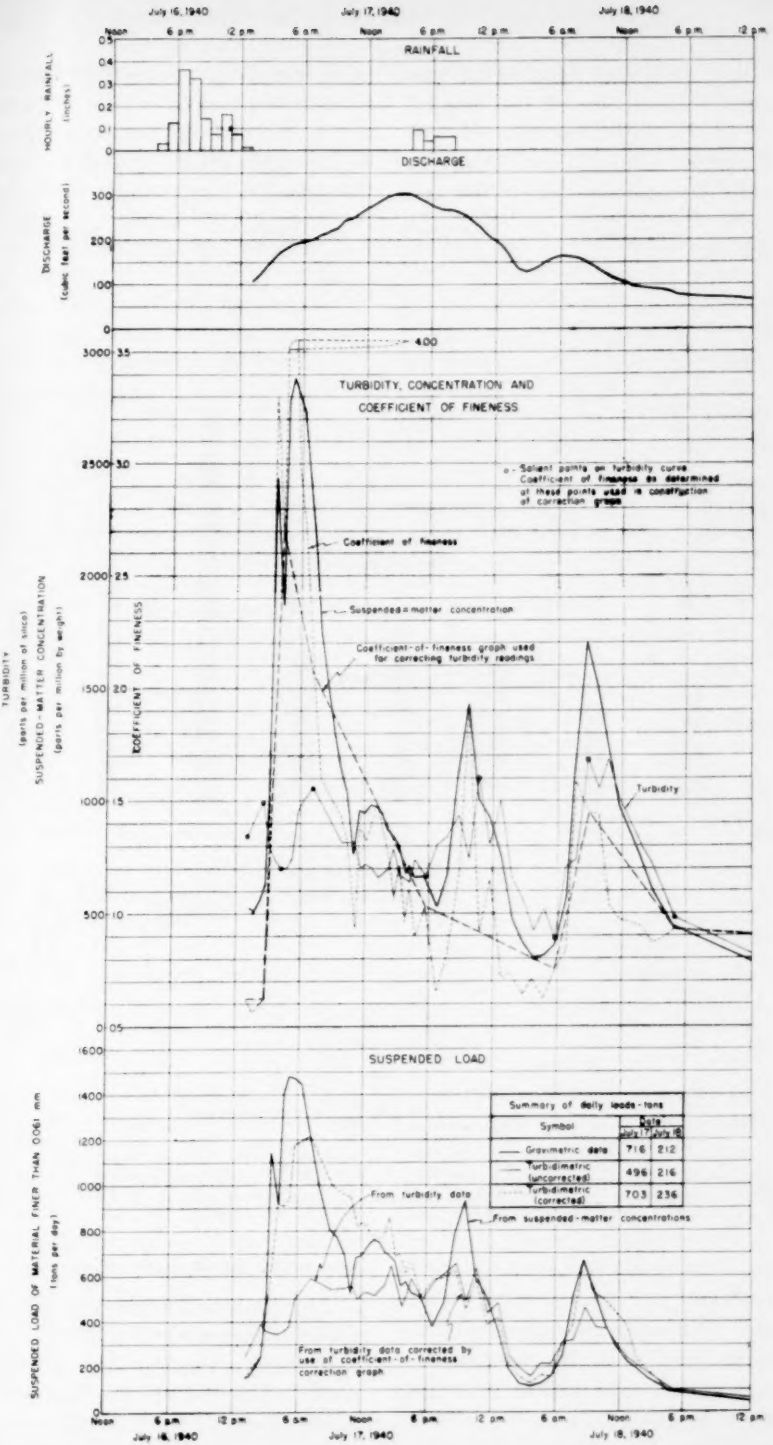

FIG. 5. Summary of Rainfall, Discharge, Turbidity, Suspended-Matter Concentration, Coefficient of Fineness and Suspended Load for Enoree River Flood of July 17–18, 1940

It has been indicated, also, that the mechanical composition of the eroded material varies with the rate of soil loss. Rainfall intensity and duration might thus conceivably affect the coefficient of fineness of material supplied to the stream.

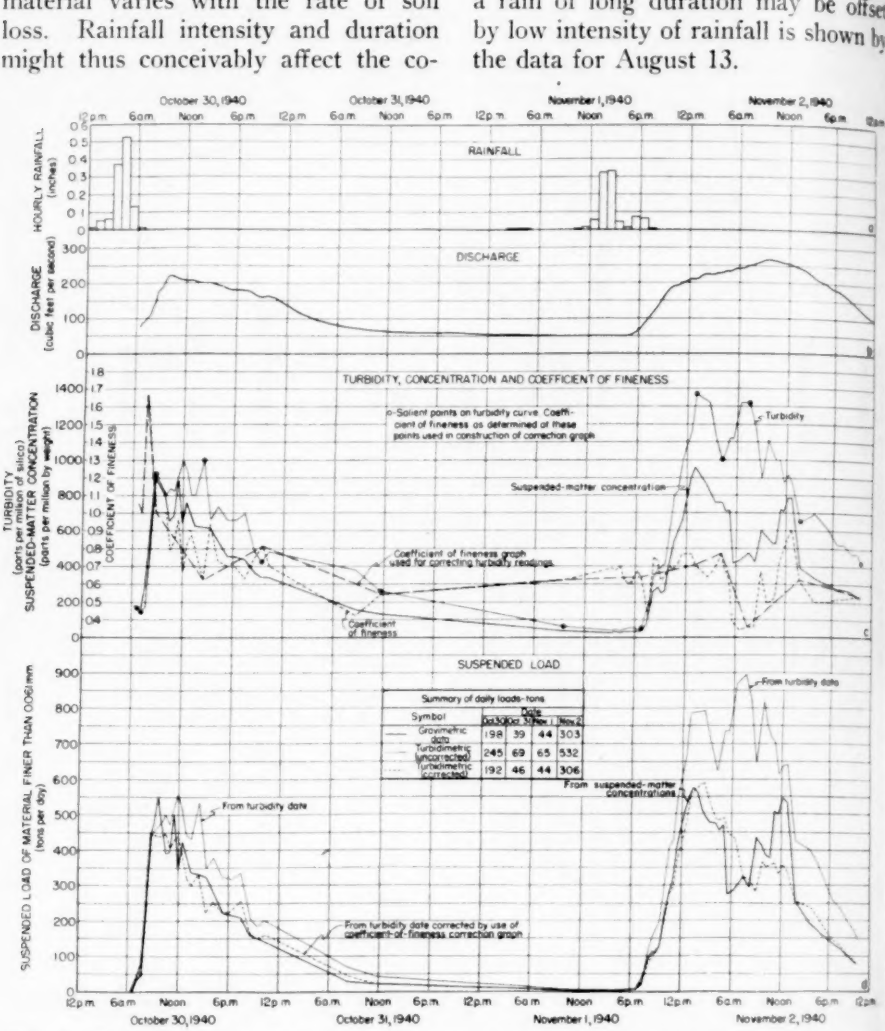

FIG. 6. Summary of Rainfall, Discharge, Turbidity, Suspended-Matter Concentration, Coefficient of Fineness and Suspended Load for Enoree River Flood of October 30–November 2, 1940

Figure 7 shows a comparison of the maximum coefficient of fineness recorded, together with the rainfall data for nine individual floods. In general, high intensity rains of long duration have produced relatively high coefficients of fineness. That the effect of a rain of long duration may be offset by low intensity of rainfall is shown by the data for August 13.

Methods of Application

The four observations enumerated above, concerning the behavior of turbidity and coefficient of fineness during rises in stage, form the basis of a suggested method for the use of turbidity readings supplemented by a few gravi-

metric determinations of suspended-matter concentration in obtaining a usable estimate of suspended load. Duplicate water samples are taken throughout a flood. Turbidity determinations are made on one sample from each pair taken, the second being stored temporarily. Turbidity is plotted against time. Where breaks in the trend of the turbidity curve occur, gravimetric suspended-matter determinations are made on the second sample taken and the coefficient of fineness calculated. The coefficients are plotted against time and connected by straight lines. Each turbidity measurement is corrected by multiplying by the appropriate coefficient as interpolated from the fineness coefficient graph. The corrected turbidity measurements are then used to calculate the suspended load in the same manner as suspended-matter concentration would be used. Application of the method is illustrated by Figs. 5 and 6. If desirable, both turbidity and suspended matter may be determined on the same sample.

Since the coefficient of fineness appears to have random distribution during normal stages and since transportation is small during these stages, thus eliminating the necessity of weighting individual determinations, the average coefficient for the year could feasibly be used in calculating transportation for these stages. A random sample, furnishing an estimate of the average coefficient, may be obtained by taking the average of determinations made on the first and fifteenth day of each month, or the day nearest these which is unaffected by abnormal stages or unusual conditions.

A comparison of three methods of calculating the suspended load of the Enoree River for 1940 is given in

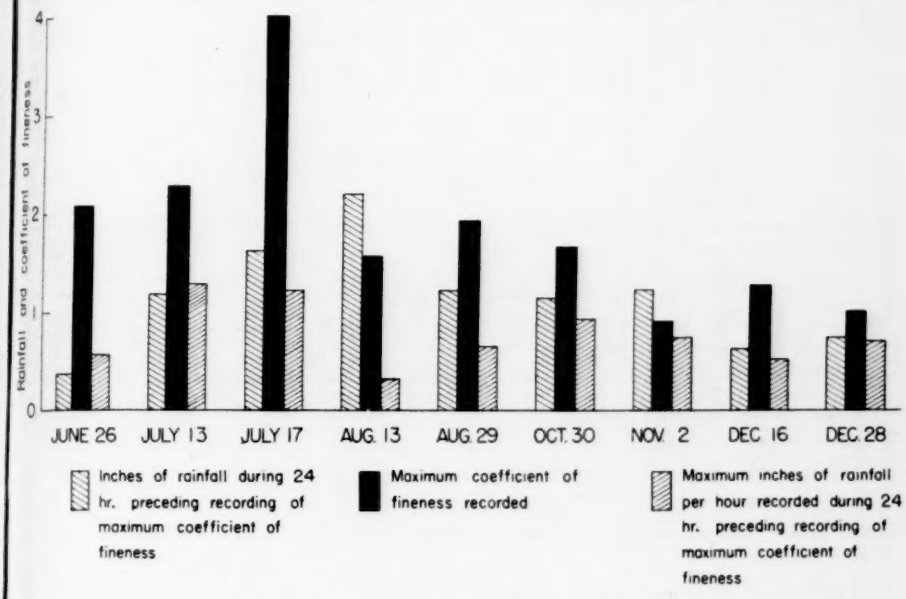

Fig. 7. Comparison of Maximum Coefficient of Fineness and Rainfall Data for Individual Rises in Stage

TABLE 2

Comparison of Gravimetric and Turbidimetric Methods of Calculating Suspended Load of Enoree River for the Year 1940

Period or Day	Method 1, Gravimetric			Method 2, Turbidimetric					Method 3, Turbidimetric, Corrected					
	Suspended Load		Detns. of Concn.	Suspended Load				No. of Turbidity Readings	Suspended Load				No. of Detns.	
	Normal Stages	Stages Above Normal		Normal Stages		Stages Above Normal			Normal Stages		Stages Above Normal			
				Amount	Error	Amount	Error		Amount	Error	Amount	Error	Gravimetric	Turbidimetric
	tons	*tons*		*tons*	*%*	*tons*	*%*		*tons*	*%*	*tons*	*%*		
January	265		11	193	−27			11	212	−20			2	11
Jan. 15		153	7			126	−18	7			153	0	3	7
February	220		17	139	−37			17	153	−30			2	17
Feb. 18–20		681	18			572	−16	18			682	+0.1	5	18
March	477		25	347	−27			25	382	−20			2	25
Mar. 14		47	8			45	− 4	8			46	−2	5	8
April	189		31	164	−13			31	180	− 5			2	31
May	95		30	79	−17			30	87	− 8			2	30
June	148		33	105	−29			33	116	−22			2	33
June 26		169	9			103	−39	9			167	−1	5	9
July	191		30	156	−18			30	172	−10			2	30
July 10		64	7			70	+ 9	7			66	+3	2	7
July 17–18		928	50			712	−23	50			939	+1	12	50
August	100		23	102	+ 2			23	112	+12			2	23
Aug. 29–30		413	53			623	+51	53			420	+2	9	53
September	158		30	193	+22			30	212	+34			2	30
October	138		29	92	−33			29	101	−27			2	29
Oct. 30–31		238	23			313	+32	23			238	0	7	23
November	229		30	247	+ 8			30	272	+19			2	30
Nov. 1–2		348	46			597	+72	46			350	+0.6	8	46
December	182		26	253	+39			26	278	+53			2	26
Dec. 16–17		139	38			154	+11	38			142	+2	8	38
Dec. 27–29		472	49			686	+45	49			470	−0.4	11	49
Total suspended load	2,392	3,652	623	2,070	−13	4,002	+10	623	2,277	− 5	3,673	+0.6	99	623

Table 2. Method 1 employed concentration of suspended matter determined gravimetrically. For normal stages, concentration and average discharge were used to determine daily transportation. For rises in stage, concentration and instantaneous discharge were used in calculating the ordinates of the suspended-load curve, the transportation being obtained from the area beneath the curve. Method 2 is identical with method 1, except that turbidity is substituted for suspended-matter concentration. Method 3 is the same as method 2 except that turbidities are corrected on the following basis: For normal stages, turbidities are multiplied by the arithmetic average of coefficients of fineness determined on the first and fifteenth of each month, or the nearest day unaffected by rises in stage or unnatural conditions. For rises in stage, turbidities are corrected by use of a coefficient of fineness graph constructed as previously explained. Each method uses comparable data and is based on the same number of samples taken at the same time. Three flood stages occurring in 1940 are not included because of incompleteness of the data. It must be remembered, too, that only suspended sediment finer than 0.061 mm. is included in the gravimetric calculations.

The close agreement between the yearly totals obtained by methods 1 and 2 is interesting, but the great differences between results for short periods indicate that the agreement is largely coincidental. The possibility that the standard silica suspension used in calibrating this particular turbidimeter approximates an average for material in the Enoree at this location is suggested. This possibility is more clearly indicated by an examination of Fig. 8, in which the average concentrations of suspended matter corresponding to scale readings of the tur-

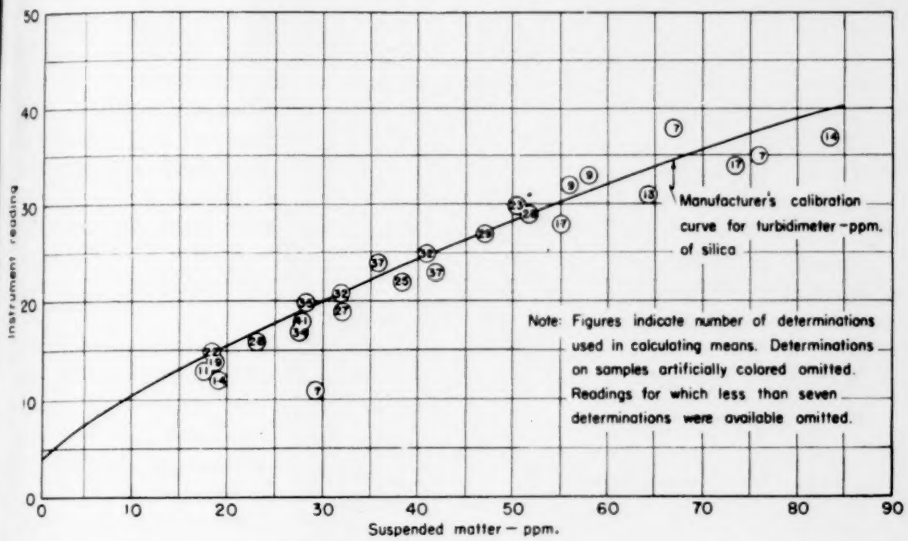
Instrument reading
Suspended matter — ppm.
Manufacturer's calibration curve for turbidimeter — ppm. of silica
Note: Figures indicate number of determinations used in calculating means. Determinations on samples artificially colored omitted. Readings for which less than seven determinations were available omitted.

FIG. 8. Comparison of Scale Reading of Turbidimeter With Means of Suspended-Matter Determinations

bidimeter are plotted. The manufacturer's calibration curve is also shown. The approximation of the plotted points to the calibration curve is striking.

Suspended-load calculations based on corrected turbidity readings agree very closely with those based on the gravimetric method, both with respect to individual floods and yearly totals. The fact that 654 turbidity readings supplemented by 99 gravimetric determinations give, for all practical purposes, the same result (— 1.6 per cent for the year) as 654 gravimetric determinations, indicates the possibility of a considerable reduction in laboratory costs. Cost records at the Sedimentation Division laboratory show that a turbidity measurement may be made at less than one-third the cost of a gravimetric determination of suspended matter. The corrected turbidity method would thus effect a laboratory cost reduction of more than 50 per cent for a program of the scope of that shown in Table 2.

Conclusions

The relation of turbidity to suspended matter in the Enoree River follows a definite pattern. Similar patterns may or may not exist in other rivers, but detailed investigation of the relation of turbidity to suspended matter appears to be warranted where the establishment of such relations would be of value in estimating suspended load.

Old turbidity measurements must be used with extreme caution for estimating past transportation of suspended sediment. To use past records the following points must be established:

1. The original turbidity standard used must have been constant and must either be available for use in conjunction with current investigations or be capable of accurate reproduction. Measurements based on comparison with standard suspensions are especially susceptible to error as pointed out by Wells (3), who found wide variation in the turbidity of supposedly standard suspensions.

2. The turbidity records must be supplemented by discharge records.

3. There must be no reason for suspecting that the average coefficient of fineness has not remained reasonably constant at the point of measurement. Changes in average coefficient may be anticipated if conditions in the drainage area have changed radically with respect to land use or to pollution of the stream by municipal or industrial sewage. Great changes in the quantity of transported sediment, as indicated by major changes in turbidities, may have been accompanied by change of coefficient.

4. Turbidity measurements correlated against gravimetric determinations of suspended matter over a sufficiently long period must show a reasonably definite average relation of turbidity to suspended matter.

In future suspended-load investigations, turbidity measurements supplemented by a few gravimetric determinations may cut laboratory costs considerably, with little or no reduction in accuracy. The reliability of this method, however, should be verified for the particular conditions encountered, by sufficient comparisons of turbidity and suspended-matter concentration. Such comparisons may indicate an average relationship which could be used to obtain sufficiently accurate results in a long-term suspended-load measuring program, without supplementary gravimetric analyses. Because of the great variation of

the fineness coefficient, especially during flood stages when transportation is greatest, suspensions of river silt should not be used as turbidity standards unless their reliability is checked over a sufficient period.

The author is grateful to Mark P. Connaughton, Hans A. Einstein and Joe W. Johnson of the Sedimentation Division of the Soil Conservation Service for their valuable suggestions and criticism. The careful work of Harold D. Stalvey, who made the greatest share of the turbidity measurements, also deserves mention.

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Erratum

Manual of Recommended Water Sanitation Practice Accompanying United States Public Health Service Drinking Water Standards, 1942, in the February 1943 issue:

Page 153, denominator of fifth equation (Factor A): *for* $1 - \frac{11.22 \times 10^{-11}}{(H^+)}$, *read* $1 + \frac{11.22 \times 10^{-11}}{(H^+)}$

TENTATIVE STANDARD SPECIFICATIONS

for

FILTERING MATERIAL

The American Water Works Association has approved and promulgates these Tentative Specifications for Filtering Materials as prepared in the course of the activities of the Water Purification Division and under the jurisdiction of the Committee on Water Works Practice. The requirements are based upon long term experience and are intended to be applied in the construction of filtration plants operating under normal conditions. They are not designed for unqualified use under all conditions and the advisability of use of the material herein specified for any installation must be subjected to review by the engineer responsible for the installation in the particular locality concerned.

Approved by the Board of Directors of the A.W.W.A., March 1943

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Personnel of Committee

PAUL HANSEN, *Chairman*
H. E. HUDSON JR.
CHARLES G. HYDE
W. H. KNOX
GEORGE R. SPALDING
WILLIAM E. STANLEY

TENTATIVE STANDARD SPECIFICATIONS FOR FILTERING MATERIAL

Section 1—Scope

The purpose of these specifications is to provide a general basis for choosing underdrain gravel and filtering material and placing such material in the filter.

Section 2—Underdrain Gravel

Sec. 2.1—Physical Characteristics

The gravel shall be obtained from an approved source and shall consist of hard, rounded pebbles with an average specific gravity of not less than 2.50. Not more than 1 per cent by weight of the material shall have a specific gravity of 2.25 or less. The gravel shall not contain more than 2 per cent by weight of thin, flat, or elongated pieces determined by hand picking and the gravel shall be free of shale, sand, clay, loam, and organic impurities of any kind.

Sec. 2.2—Solubility

When pulverized so that all will pass a 20-mesh sieve and digested for 24 hr. in a 20 per cent solution of hydrochloric acid as HCl, no more gravel shall be soluble than given as the limit for each size in Table 1.

Sec. 2.3—Gravel Sizes and Thickness of Layers

The gravel shall be sieved to proper sizes and placed in each filter in layers as specified in Table 2.[1] The gravel of each of the layers listed in Table

TABLE 1

Limits for Gravel Solution

Diameter of Gravel Particles	Permitted Solubility
Over 1 in. or 25 mm.	15 per cent
Between 3/8 in. and 1 in. or 10 mm. and 25 mm.	10 per cent
Under 3/8 in. or 10 mm.	5 per cent

TABLE 2

Gravel Sizes and Thickness of Layers

Layer	Size Limits	Thickness of Layer in Inches*
Bottom	1.0 in. to 2.5 in. (25.4 mm. to 64 mm.) (or such other size as the engineer thinks appropriate)	
Second	1/2 in. to 1 in. (12.7 mm. to 25.4 mm.)	
Third	1/4 in. to 1/2 in. (6.35 mm. to 12.7 mm.)	
Fourth	1/8 in. to 1/4 in. (3.18 mm. to 6.35 mm.)	
Fifth	1/16 in. to 1/8 in. (1.6 mm. to 3.18 mm.)	

* The engineer will supply figures for layer thickness according to his judgment.

[1] While the Committee stipulates no standard depth for gravel layers, it records, for information, the following example: bottom layer, 4 in. or enough to cover underdrain pipes adequately; other layers, 3½ in.

2 shall be uniformly graded. Wire screens with square openings or plates with round openings may be used for screening the gravel over ¼ in. in diameter; but wire screens shall be used for sizes smaller than ¼ in. The average diameter of the particle which will just pass through a given sieve opening shall be assumed to be that of a sphere. This assumption shall apply only to material large enough not to pass through a 10-mesh sieve.

The porosity of the material as measured in a glass tube under conditions simulating a filter wash shall not exceed 45 per cent (or other porosity that the engineer may in his judgment designate).

Sec. 2.4—Placing Underdrain Gravel

Before placing the underdrain gravel, the filter tank shall be thoroughly cleaned. No dirt or foreign matter of any kind shall be allowed to enter the filters after beginning to place the gravel. Gravel made dirty in any way shall be removed and replaced with clean gravel. Each layer of gravel shall be placed and leveled before placing any portion of the layer next above. The gravel in the bottom of the filter shall be hand-placed, care being taken not to place stones where they will obstruct the flow of water in washing the filters.

After each layer of gravel is placed, water shall be added to the filter to the level to which the top of the gravel level should extend. With the water at the proper level, none of the particles of the gravel shall be less than one-half submerged and there shall not be places where additional gravel can be placed without the particles extending more than one-half their volume above the water level. Workmen with rakes shall level the gravel of each layer as uniformly as possible. For materials less than ½ in. in diameter, the workmen shall not stand or walk directly upon the gravel but upon boards which will sustain the weight of the workmen without displacing the gravel. Any gravel becoming mixed shall be removed and replaced in layers as herein specified.

Section 3—Filtering Material

Sec. 3.1—Physical Characteristics

The filtering material shall comprise all material less than 1.6 mm. in diameter and shall be obtained from an approved source. It shall be composed of hard, durable grains free of clay, loam, dirt, and organic matter (except in case of anthracite) and not more than 1 per cent shall be flat or micaceous particles.

Sec. 3.2—Solubility

After immersion for 24 hr. in 20 per cent hydrochloric acid as HCl, the material shall not have lost more than 5 per cent of its original weight.

Sec. 3.3—Size of Material

The size of the filtering material shall be determined by sieving in calibrated sieves, the calibration and sieving being carried out in a manner described in the *Water Works Practice Manual* of the American Water Works Association published in 1925 (*see* Appendix A). The diameter of grains shall be computed as the diameter of spheres of equal volume. The per cent sizes shall be determined from a chart in which the percentages of the material passing sieves of openings of various sizes are plotted against the diameter of the grains. When thus plotted

the size distribution shall be as shown in Table 3.

Sec. 3.4—Depth of Filter Sand

The depth of the filtering material shall be .... inches (to be fixed by the purchaser). For the purpose of measuring the depth and quantity of the material it shall be backwashed at a rate to give approximately 30 per cent expansion of the filter unit, after which the backwash valve shall be closed very slowly. The time required to close the backwash valve from a rate

TABLE 3

Size Distribution—Sizes Given in Millimeters of Diameter

Per Cent of Material by Weight of Diameter and Smaller	Desired Size	Minimum Size	Maximum Size
1	(		)
2	(		)
4	(		)
8	(	To be listed by engineer	)
10	(		)
16	(		)
32	(		)
60	(		)

which gives about 10 per cent expansion of the filter unit to the closed position shall be not less than 30 sec. The process should be repeated three times with a view to obtaining the greatest compaction of the filtering material, after which the depth of the material shall be measured for payment.

Sec. 3.5—Placing Filtering Material

Care shall be taken in transporting and placing filtering material to prevent contamination of any sort, and material which may have become dirty either before or after placing in the filters shall be washed or shall be removed and replaced by clean material in a satisfactory manner. After the filtering material has been placed in the filters the contractor shall protect it, as may be necessary, from dirt or other contamination.

Section 4—Testing and Sampling

Before shipment, the contractor shall furnish for testing, samples of filtering material and underdrain gravel consisting of not less than 1 qt. each of filtering material and not less than ½ cu.ft. of gravel. Each sample shall be labeled and shall state the place from which it has been taken. One sample of filtering material shall be furnished from each 10 cu.yd. of filtering material and one sample of gravel from each carload or each 30 cu.yd. of gravel. All samples shall be furnished in tight receptacles. The filtering material and gravel shall be tested by the purchaser and/or his engineer to determine conformity or nonconformity with the specifications; if the sample is unsatisfactory, the material represented by the sample shall be rejected. After delivery of the filtering material, additional samples may be taken by the purchaser and/or his engineer; if this material upon analysis does not conform with samples submitted and approved, the material will be rejected.

Section 5—Payment

The lump sum (unit price) to be paid for this item, as set forth in the contract hereto attached, shall be compensation in full for all of the work complete in place as shown on the plans, described and specified to be included and carried out under this item.

Appendix A

Calibration of Sieves

From the Manual of Water Works Practice

The entire statement of "Calibration of Sieves" is reproduced here because the method is still valid and the Manual of Water Works Practice *is no longer in print or generally available.*

Sieves are made from carefully selected brass wire cloth having as nearly as possible square and even sized meshes. The frames are of metal, fitting one to another and the last to a pan at the bottom so that there will be no loss of material. The wire cloth may be bought in large pieces, carefully inspected and a number of sets of sieves made as nearly as possible alike from these pieces. A serial number is stamped on each sieve in small figures for permanent record. After the size of separation is determined, as described below, that size should also be stamped on it but in larger and more conspicuous figures.

The dimensions of wire cloth recommended by the Bureau of Standards are shown in the JOURNAL (Jour. A.W.W.A., **5**: 345 (1918)).[A1]

It has not been found possible to get a number of sieves that will give exactly the same size of separation. Even among sieves made from the same piece of wire cloth there will be variations. A great deal of time and ingenuity has been spent in trying to make the sieves interchangeable. An approximation to this result can be accomplished; but it is not necessary and if accomplished would make no material change in present methods or results.

With the mass system of plotting the line resulting from plotting the analysis of a given sample made by any rated sieves should be the same within reasonable error limits as that resulting from the use of any other rated set.

The number of sieves to be used and the relation between their sizes of separation have been frequently discussed. The requirements vary according to the kind of sand and the purposes for which it is to be used. In examining bank sands and sands for sand filters having uniformity coefficients of 2.5 and over, a set of sieves in which there is a ratio of approximately 2 to 1 between sizes of separation of each sieve and the next will answer. In examining even grained sands with uniformity coefficient under 2.0, such as are used in mechanical filters, at least one intermediate sieve, between each two such sieves, is needed. In some offices screen openings having a ratio of the $\sqrt{2}$ to each other are preferred. The greatest interest in filter sand will be as to the size of particles ranging from 0.30 to 0.60 mm. and two or three extra sieves in this range will be helpful. A liberal number of sieves in a set is advantageous; but in any particular analysis, only those sieves necessary to the purpose in hand should be used. It will never be necessary to use the whole of a full set at one time. A set of sieves can frequently be split into two sets, putting every alternate sieve in one set and the other in another. Such split sets will be ample for many purposes, and it should make no material difference in the results which of the two sets is used.

Specifications for sieves have been prepared by the United States Bureau of Standards and by the American Society for Testing Materials.

The finest wire cloth available for making sieves has about 200 meshes per lineal inch and the size of separation found for it is usually between 0.100 to 0.110 mm. That cloth and one of the two of the next coarser sizes, are woven with a twill, two over and two under and have quite different sifting qualities from coarser cloth woven, one over and one under.

[A1] Since the publication of this material in the JOURNAL, the American Standards Association has developed "Standard Specifications for Sieves for Testing Purposes —ASA Z23.1–1939." This is available from the ASA 29 West 39th St., New York, N.Y., at 25 cents per copy. Table 1 from that document is reproduced herewith as Table A1.

TABLE A1

(Table 1 From ASA No. Z23.1–1939)

Nominal Dimensions, Permissible Variations, and Limits for Woven Wire Cloth of Standard Sieves

Size or Sieve Designation	Sieve Opening		Permissible Variations in Average Opening, per cent	Permissible Variations in Maximum Opening,[a] per cent	Wire Diameter	
	mm.	in. (approx. equivalents)			mm.	in. (approx. equivalents)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Coarse Series						
(4.24-in.)**	107.6	4.24	±2	+3	5.6 to 9.7	0.220 to 0.380
4-in.	101.6	4.00	±2	+3	5.6 to 9.7	0.220 to 0.380
3½-in.	88.9	3.50	±2	+3	5.3 to 9.3	0.210 to 0.365
3-in.	76.2	3.00	±2	+3	4.8 to 8.1	0.190 to 0.320
2½-in.	63.5	2.50	±2	+3	4.4 to 7.1	0.175 to 0.280
(2.12-in.)**	53.8	2.12	±2	+3	4.1 to 6.2	0.160 to 0.245
2-in.	50.8	2.00	±2	+3	4.1 to 6.2	0.160 to 0.245
1¾-in.	44.4	1.75	±2	+3	3.8 to 5.7	0.150 to 0.225
1½-in.	38.1	1.50	±2	+3	3.7 to 5.3	0.145 to 0.210
1¼-in.	31.7	1.25	±2	+3	3.5 to 4.8	0.140 to 0.190
(1.06-in.)**	26.9	1.06	±3	+5	3.43 to 4.50	0.135 to 0.177
1-in.	25.4	1.00	±3	+5	3.43 to 4.50	0.135 to 0.177
⅞-in.	22.2	0.875	±3	+5	3.23 to 4.22	0.127 to 0.166
¾-in.	19.1	0.750	±3	+5	3.10 to 3.91	0.122 to 0.154
⅝-in.	15.9	0.625	±3	+5	2.74 to 3.43	0.108 to 0.135
(0.530-in.)**	13.4	0.530	±3	+5	2.39 to 3.10	0.094 to 0.122
½-in.	12.7	0.500	±3	+5	2.39 to 3.10	0.094 to 0.122
7/16-in.	11.1	0.438	±3	+5	2.23 to 2.84	0.088 to 0.112
⅜-in.	9.52	0.375	±3	+5	2.11 to 2.59	0.083 to 0.102
5/16-in.	7.93	0.312	±3	+5	1.85 to 2.36	0.073 to 0.093
(0.265-in.)**	6.73	0.265	±3	+5	1.60 to 2.11	0.063 to 0.083
¼-in. (No. 3)	6.35	0.250	±3	+5	1.60 to 2.11	0.063 to 0.083
Fine Series[b]						
5660 micron (No. 3½)	5.66	0.223	±3	+10	1.28 to 1.90	0.050 to 0.075
4760 micron (No. 4)	4.76	0.187	±3	+10	1.14 to 1.68	0.045 to 0.066
4000 micron (No. 5)	4.00	0.157	±3	+10	1.00 to 1.47	0.039 to 0.058
3360 micron (No. 6)	3.36	0.132	±3	+10	0.87 to 1.32	0.034 to 0.052
2830 micron (No. 7)	2.83	0.111	±3	+10	0.80 to 1.20	0.031 to 0.047
2380 micron (No. 8)	2.38	0.0937	±3	+10	0.74 to 1.10	0.0291 to 0.0433
2000 micron (No. 10)	2.00	0.0787	±3	+10	0.68 to 1.00	0.0268 to 0.0394
1680 micron (No. 12)	1.68	0.0661	±3	+10	0.62 to 0.90	0.0244 to 0.0354
1410 micron (No. 14)	1.41	0.0555	±3	+10	0.56 to 0.80	0.0220 to 0.0315
1190 micron (No. 16)	1.19	0.0469	±3	+10	0.50 to 0.70	0.0197 to 0.0276
1000 micron (No. 18)	1.00	0.0394	±5	+15[a]	0.43 to 0.62	0.0169 to 0.0244
840 micron (No. 20)	0.84	0.0331	±5	+15[a]	0.38 to 0.55	0.0150 to 0.0217
710 micron (No. 25)	0.71	0.0280	±5	+15[a]	0.33 to 0.48	0.0130 to 0.0189
590 micron (No. 30)	0.59	0.0232	±5	+15[a]	0.29 to 0.42	0.0114 to 0.0165
500 micron (No. 35)	0.50	0.0197	±5	+15[a]	0.26 to 0.37	0.0102 to 0.0146
420 micron (No. 40)	0.42	0.0165	±5	+25[a]	0.23 to 0.33	0.0091 to 0.0130
350 micron (No. 45)	0.35	0.0138	±5	+25[a]	0.20 to 0.29	0.0079 to 0.0114
297 micron (No. 50)	0.297	0.0117	±5	+25[a]	0.170 to 0.253	0.0067 to 0.0100
250 micron (No. 60)	0.250	0.0098	±5	+25[a]	0.149 to 0.220	0.0059 to 0.0087
210 micron (No. 70)	0.210	0.0083	±5	+25[a]	0.130 to 0.187	0.0051 to 0.0074
177 micron (No. 80)	0.177	0.0070	±6	+40[a]	0.114 to 0.154	0.0045 to 0.0061
149 micron (No. 100)	0.149	0.0059	±6	+40[a]	0.096 to 0.125	0.0038 to 0.0049
125 micron (No. 120)	0.125	0.0049	±6	+40[a]	0.079 to 0.103	0.0031 to 0.0041
105 micron (No. 140)	0.105	0.0041	±6	+40[a]	0.063 to 0.087	0.0025 to 0.0034
88 micron (No. 170)	0.088	0.0035	±6	+40[a]	0.054 to 0.073	0.0021 to 0.0029
74 micron (No. 200)	0.074	0.0029	±7	+60[a]	0.045 to 0.061	0.0018 to 0.0024
62 micron (No. 230)	0.062	0.0024	±7	+90[a]	0.039 to 0.052	0.0015 to 0.0020
53 micron (No. 270)	0.053	0.0021	±7	+90[a]	0.035 to 0.046	0.0014 to 0.0018
44 micron (No. 325)	0.044	0.0017	±7	+90[a]	0.031 to 0.040	0.0012 to 0.0016
37 micron (No. 400)	0.037	0.0015	±7	+90[a]	0.023 to 0.035	0.0009 to 0.0014

** The five sieves marked in the first column with a double asterisk (**) may be used instead of the 4-in., 2-in., 1-in., ½-in., and ¼-in. sieves when it is desired to have a series of sieves nesting with the Fine Series and continuing that series with the $\sqrt[4]{2}$: 1 ratio. All of the other sieves listed above are in $\sqrt[4]{2}$: 1 ratio with the Fine Series within the limit of the specified permissible variations. Care should be taken in designating the five sieves marked with the double asterisk; they should not be designated as 4-in., 2-in., 1-in., ½-in., and ¼-in., but as 4.24-in., 2.12-in., 1.06-in., 0.530-in., and 0.265-in. (or by the manufacturer's nominal values, for example, for the last three 1.050-in., 0.525-in., and 0.263-in.).

[a] For sieves from the 1000-micron (No. 18) to the 37-micron (No. 400) size, inclusive, not more than 5 per cent of the openings shall exceed the nominal opening by more than one-half of the permissible variation in maximum opening.

[b] See Note 2, Section 2.

The coarsest wire mesh to be used has 20 meshes per inch. All coarser sieves are better made from perforated metal plates. These are more uniform and satisfactory than large mesh wire cloth.

Sieves are surprisingly durable when carefully handled; but it is well to recheck the rating at intervals. Leaks sometimes develop, and these are disclosed by rerating. Leaks may result from accidents to the cloth which enlarge some of the holes, or the cloth may get loose from the metal sides of the sieves. In either case the leaks can be stopped by solder; and it is a good plan to go over old sieves occasionally with a soldering iron, closing possible points of leakage.

Irregularities in Plotting

An irregular line, that is to say, one with sharp bends either up or down, shows badly rated sieves or defective methods of sifting. If sieves do not show good consistent plottings with fairly direct lines, the rating and methods of sifting ought to be at once investigated. Inadequate shaking or a leak may be the cause. Some irregularity at the upper end is unavoidable, because with 50 or 100 gram samples, a single particle weighs so much as to make a difference in the plotting at the top. Such irregularities must be passed as of no significance.

The curvature of the line at the bottom is of fundamental importance. When a line bends down at the fine end of the regular plotting (or up on probability paper), it means that the fine material has been removed, usually by washing or some artificial process so that it is unusually free from small particles and is cleaner than normal sand. When the line at the bottom curves upward on the regular plotting (or downward on probability paper), it indicates that there is an excess of fine particles such as might, for instance, be found in a sand in a filter resulting from accumulation of particles taken from the water being filtered. In general, a normal sand gives a direct line to the end and in some cases almost a straight line.

Definition of Size of Grain

The size of grain of granular material is defined as the diameter of a sphere of equal volume.

The size of grain is always the ultimate standard. The size of mesh or opening is not to be substituted for it.

When sieves with rectangular or round openings are used and with all other methods of separation, the method should be tested out as far as possible to ascertain the actual size of separation for that particular sieve or procedure and the result should be stated in grain size rather than in terms of sieve openings. The reasons for this will be stated below.

At Lawrence, Mass., it was found, as the average of numerous measurements, that the three axes of the grain, selecting the longest possible and taking the other two at right angles to it, are as 1.38, 1.05, and 0.69 to the mean diameter. The cube root of their product is a close approximation to the mean.

Rating

It can be easily shown by experiment that, when a mixed sand is shaken upon a sieve, the smaller particles pass most rapidly at first and as the shaking is continued, after the smaller particles are all out, larger particles pass until a limit is reached when almost nothing more will pass. The last and largest particles passing represent the separation of that sieve. Practically all of the material that passes in the usual analysis is finer than these last particles and practically everything that remains is coarser.

The size of separation of a sieve bears some relation to the size of mesh; but the relation varies and is not to be depended upon. There are unavoidable irregularities of the meshes in individual sieves. Moreover, particles passing the finer sieves are larger in proportion to the mesh size than is the case with coarser sieves. For these reasons the actual sizes of separation are determined by actual measurement. Elaborate measurements of meshes and wires are unnecessary and do not contribute to the accuracy of the final result.

In rating a set of sieves a representative sand sample, preferably with a uniformity coefficient that is not too low, is put in the sieves and the process of shaking is carried out precisely as it would be in an ordinary analysis. The sieves are then taken apart for further examination one at a time. If the sample taken for this purpose is of such grain size that some sieves show but little material left on them, these sieves should be discarded for the present purpose and tested

further with another sample better adapted to their rating. Sieves that have a substantial amount of sand left on them are taken one at a time and given a certain further amount of shaking. The small amount of material collected in the pan from this additional shaking will all of it be of particles of nearly the same size.

The size of these particles is now to be determined. The procedure is to count out a considerable number of them and to weigh them and to determine their size from their average weight. The size is the diameter of a sphere of equal volume. When the weight and specific gravity are known the diameter can be calculated.

The volume of a sphere is $\frac{1}{6}\pi D^3$. It is also equal to the weight divided by the specific gravity. The weights are stated in milligrams and the diameters in millimeters. The specific gravity of sand ordinarily used averages 2.65. Very few sands fall below 2.6 or above 2.7. It is well to determine the actual specific gravity of the particles of the sand being used; but in most cases 2.65 may be used. Where this is the case it is computed that $D = 0.9\sqrt[3]{W}$. The exact coefficients are: for specific gravity 2.60, 0.9023; for 2.65, 0.8966; for 2.70, 0.8910. A line drawn on 20 inch base logarithmic paper can be conveniently used for conversion, or the calculation may be made by a log slide rule.

An accurate balance for weighing the particles is necessary. The counting is best carried out by putting a small sample of sand on paper ruled in squares, covered and placed where it cannot be disturbed during the process of counting. Every sieve should be rated at least three times, preferably with different kinds of sand, and consistent results obtained before they are accepted.

The number of particles to be counted will hardly be less than 100 in any case. One hundred particles 0.4 mm. in diameter will weigh 8.8 milligrams and it will take a delicate balance to weigh these with sufficient accuracy.

For the finer sieves the number of particles that must be counted will be larger, running up to several thousand for the 200 mesh sieve. In a general way the sieves most important in filtration, 0.2 mm. and upward, will not require the counting of numbers so large as to be unduly burdensome.

For the two or three finer sieves in each set the rating by counting is more tedious and it will be better to rate a few such sieves with the utmost care and depend upon indirect or comparative rating (to be presently described) for the others.

Effect of Shape of Grains Upon Rating

The shape of the grains whether round, oval or angular makes some difference in the rating of the sieves. This matter was tested out by making 50 ratings of sieves ranging from 0.134 to 1.03 mm., or from 140 to 20 meshes per inch, with different kinds of sand. The work was done years ago by two men working independently. Several samples of each of five kinds of sand were used. Each sieve was rated on all the different kinds of sand and the average rating from all determinations taken. The relative rating with each particular kind of sand was then calculated for each sieve and these were averaged for all sieves. The average results were as shown on Table A2.

TABLE A2

Kind of Sand Used in Rating	Rating in Terms of the Mean of All
Red Wing, Minn., wind worn and almost spherical	1.012
New Jersey Sea Shore, water worn and considerably rounded	1.000
Allegheny River, originally glacial drift, but water worn	0.982
Masscahusetts Bank sand, glacial drift, sharp grained	1.004
Crushed quartz, entirely angular	1.007

From this it appears that sand that is somewhat worn and rounded gives a slightly lower rating to a sieve than either completely rounded or entirely angular grains. The entire range in results is small and not of much practical importance.

Relation Between Mesh Size and Size of Separation

The following represents approximately the relation between commercial brass wire cloth and the sizes of separation.

Meshes per in.	200	140	100	50	40	30	20
Separation in mm.	0.10	0.13	0.17	0.33	0.48	0.63	0.95

The results will vary either way from these values, which are only given as an aid in selecting proper cloth for sets of sieves.

Width of Mesh or Grain Size

It has been proposed at various times that sieves should be made with wire cloths of standard mesh, all dimensions being most carefully defined, and that such carefully made sieves should be used without rating. In this case the size of the mesh would be substituted for the grain size. This procedure has been largely adopted for sand to be used for concrete and other purposes.

Philip Burgess (Jour. A.W.W.A., **2**: 493 (1915)) sets forth the advantage of this procedure. In the discussion that followed is a statement (p. 504) of the advantages of adhering to the grain size as a basis for classification. This statement is referred to for further particulars. Both of these papers were reprinted (*Engineering Record*, **71**: 644). The Committee Report of 1918 (p. 543) contains further particulars of the sieves recommended by the Bureau of Standards, but no further discussion on the main question.

Other proposals for simplifying sand analyses and methods for stating results have been made from time to time. The "fineness modulus" method developed by Abrams should be here mentioned. The Committee Report of 1924 (Jour. A.W.W.A., **11**: 677 (1924)) should be consulted for interesting discussions of this and other possible modifications of auxiliaries to existing methods.

Comparative Rating

When sieves were first rated by weighing and counting particles at Lawrence, Mass., duplicate sieves were made and rated with the utmost care and in the thirty-five years since that time, one set of these sieves has been kept by one worker for the sole purpose of comparing with other sieves. In other words this set has been reserved as a control standard. It has been found possible, by using these and other carefully rated sieves, to obtain comparative ratings of value.

The method used is to take two old and very carefully standardized sets of sieves, such as the one above mentioned and another and ten new and untested sets of sieves. One hundred grams of sand suitable for this use are taken. These same 100 grams are put through each of the 12 sets of sieves in succession and the separations recorded. With careful manipulation the loss of material in the twelve siftings is not enough to be of importance. It should not exceed at most half a gram; but to eliminate any error that might be introduced in this way, the process is at once repeated with another sample of sand, the same sets of sieves being used; but this time in reverse order. The analyses of each sand sample taken for these tests are plotted on a special sheet of paper of much larger scale than is used in routine work. Logarithmic paper on 20-inch base is appropriate. The analysis is first plotted from the two sets of rated sieves. The results from these must be consistent and plot in a direct line. From this line and the per cents passing all the other sieves, the corresponding sizes of separation are ascertained. This process is ordinarily repeated several times so that at least three comparative figures for each sieve are obtained. With well selected samples and careful manipulation consistent and accurate results are secured. The method is a delicate one; but it is, of course, applying in an indirect way the results of the direct rating of the primary sieves.

Appendix B

Supplemental Notes

The specifications as written are based upon sand as filtering material. Materials other than sand may be used at the discretion of the engineer preparing the specifications. For example, crushed quartz and crushed anthracite coal have been more or less extensively used as filtering material and may be preferred to sand or may be used with sand advantageously under certain circumstances. The same methods of specifying as to size may be used.

Crushed quartz and crushed anthracite are not available in rounded particles; but there is no objection to using angular particles of these materials or of sand provided the engineer who writes the specifications recognizes the existence of larger voids in a filter layer of angular material and takes this factor into consideration.

It is to be noted that reference to effective size and uniformity coefficient is omitted. These terms are of no interest to the contractor but may be of interest to the engineer in considering the merits of the material for filtration purposes. Engineers differ in their opinions regarding the best means of describing hydraulic or filtering characteristics of a given filtering material. By simply specifying sieve separations in tabular form and indicating tolerances, an engineer may obtain a sand which best meets with his conception of desirable hydraulic and filtering qualities. As indicated in this Committee's Progress Report of 1941 (Jour. A.W.W.A., **33**: 2021 (1941)), other expressions are being proposed for describing the hydraulic and filtering characteristics of sand such as "effective size range in per cent by weight"

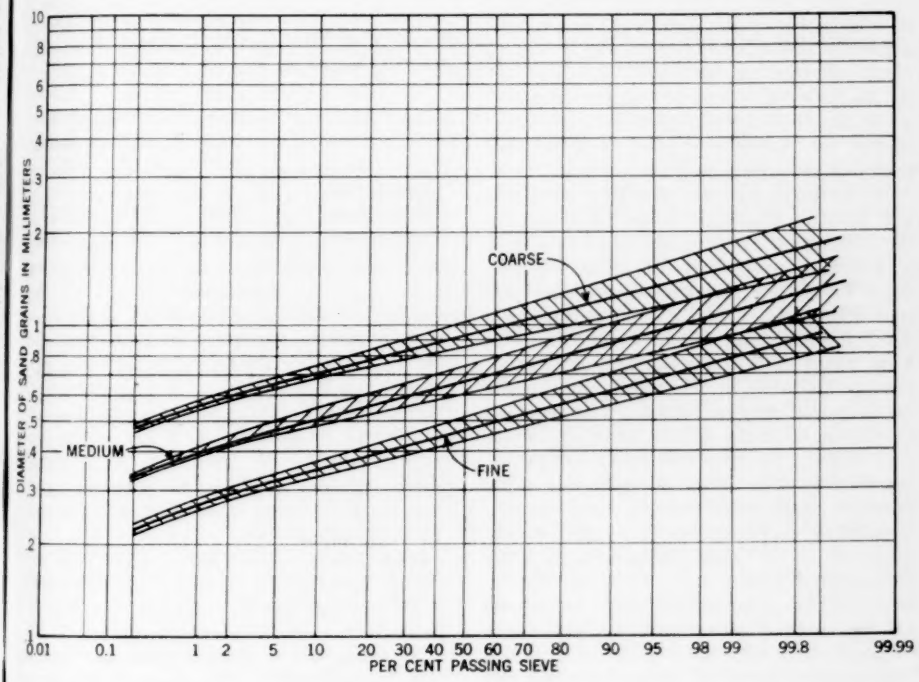

FIGURE 1

and "mean diameter within the effective size range." The shape of the curve obtained by plotting the sieve analysis of filtering material permits the engineer to study a given material in the light of any of these expressions. Accordingly, there is herewith shown plotted on logarithm-probability paper a series of curves indicating three filter sands, fine, medium, and coarse. All would qualify as good sands whether described by the terms "effective size" and "uniformity coefficient" or by the terms "effective size range in per cent by weight" or "mean diameter within the effective size range."

In specifications the three sands would be described in tabular form as shown in Table B1.

The engineer may draw a curve which he regards most suitable for his particular filtration problem and specify a material conforming to the curve by size separations which is the only characteristic that concerns the dealer in filtering material.

It is observed that the method of calibrating sieves and making sieve analyses as described in the *Water Works Practice Manual* is still retained as a standard (see Appendix A). This is done because commercial testing sieves are not as yet made with sufficiently low tolerances and uniformity to permit determining accurately the sizes of filtering material. If at any time commercial testing sieves are produced that can be used reliably, the elaborate method of calibrating developed by Hazen may be omitted.

The thickness and size of filter gravel will vary with the character of the filter bottom. The illustration given in the specifications is for a gravel layer 18 in. or more in thickness. The greater thicknesses of gravel are applicable to filter bottoms consisting of a pipe grid with holes drilled in the underside of the pipe. If Wheeler bottoms or Wagner bottoms are used in the filters, the largest size of gravel may be omitted, thus reducing the thickness of the gravel layer to 14 in., or if desired, the new bottom layer may be increased by 2 or 3 in. With certain other types of underdrain systems, such as the so-called Leopold system, the two bottom layers of gravel may be omitted, thereby reducing the gravel layer to about 10½ in. With porous plate underdrains, the gravel may be omitted altogether; but preferably the fourth and fifth layer might be retained. The engineer should be allowed considerable latitude both as to the thickness of gravel layers and the size of gravel, especially of the larger sizes. These comments are not intended as an endorsement of any particular type of underdrain system.

TABLE B1

Per Cent of Material by Weight of Diameters and Smaller	Desired Size, mm.	Minimum Size, mm.	Maximum Size, mm.
Coarse Sand			
1	0.55	0.54	0.56
2	0.59	0.58	0.61
4	0.64	0.62	0.67
8	0.69	0.67	0.72
10	0.70	0.68	0.73
16	0.73	0.71	0.80
32	0.83	0.79	0.90
60	0.98	0.90	1.20
(*Characteristics*)			
Effec. Size	0.70	0.68	0.72
Unif. Coef.	1.4	1.32	1.64
Medium Sand			
1	0.39	0.38	0.41
2	0.42	0.41	0.45
4	0.46	0.44	0.49
8	0.49	0.47	0.53
10	0.50	0.48	0.54
16	0.53	0.51	0.58
32	0.60	0.56	0.66
60	0.70	0.63	0.79
(*Characteristics*)			
Effec. Size	0.50	0.48	0.55
Unif. Coef.	1.4	1.31	1.46
Fine Sand			
1	0.27	0.26	0.28
2	0.28	0.27	0.30
4	0.31	0.30	0.33
8	0.34	0.33	0.36
10	0.35	0.34	0.37
16	0.37	0.36	0.40
32	0.42	0.39	0.46
60	0.49	0.45	0.55
(*Characteristics*)			
Effec. Size	0.35	0.34	0.37
Unif. Coef.	1.40	1.32	1.49

As suggested by Baylis, a formula may be used for determining the depth of any given size of gravel in millimeters of diameter

below the top gravel which is taken as 1.6 mm. in diameter ($\frac{1}{16}$ in.) by the formula

$$M = K \times \log D - 2.5$$

in which M is the depth in inches below the top gravel

K is a coefficient taken as 11.62824 or say 11.63 and such as to give a thickness of $3\frac{1}{2}$ in. to gravel layers in which the smallest gravel has one-half the diameter of the largest

D is the diameter of gravel at any depth M below the top gravel which has a diameter of 1.6 mm.

The formula is obtained by drawing a straight line on semi-logarithmic paper in the following manner:

Beginning on the logarithmic scale at 1.6 (diameter of smallest gravel) draw a straight line so that it will pass through 3.18 (diameter of $\frac{1}{8}$-in. gravel which is twice as large as $\frac{1}{16}$-in. gravel) at a point $3\frac{1}{2}$ spaces to the right on the normal scale which signifies a gravel layer thickness of $3\frac{1}{2}$ in. Continue this straight line and it will be seen that in each $3\frac{1}{2}$ normal spaces the diameter of the gravel doubles. This equation is used in determining the thickness of all layers of gravel except the bottom one which latter is arbitrarily made of greater thickness, depending on the character of the underdrain system.

No definite depth for thickness of filtering material is indicated in the specifications. Practice varies somewhat widely from a minimum thickness of about 21 in. to a maximum thickness of about 36 in. Customary practice favors depths of 24 to 30 in. Some latitude exists for selecting depths appropriate to the particular installation; but generally speaking, the more conservative depths of from 24 to 30 in. should be used.

Appendix C

Abstracted Comments of Members of, and Advisers to, the Committee on Filtering Material

Roberts Hulbert thinks that specifications would perpetuate the present "art" of water purification instead of encouraging scientific efforts to get at the bottom of things. He thinks that a committee might accomplish more by assembling a complete statement of the present knowledge on the subject of filtering material.

William W. Hurlbut of Los Angeles thinks the specifications somewhat arbitrary in fixing a demarcation between the size of sand and gravel. He further feels that there was no adequate basis of actual scientific investigation for either the grading or thickness of gravel. He says that the chemical method suggested for determining material soluble in hydrochloric acid is insufficiently specific and might lead to different results in the hands of different chemists. The Chairman believes this might be referred to the Committee on Standard Methods of Analysis. [The specifications have been made more specific in this respect.]

In response to Hurlbut's asking if there is any experimental basis for the formula used in establishing the grading of gravel, the Chairman has said that in plotting the gravel sizes and thicknesses in specifications that have been used to date, there was found no co-ordination and, apparently, no effort to obtain a logical gradation of material. The formula proposed is simply an attempt to obtain a smooth, logical and consistent gradation. It gives a straight line "curve" on semi-logarithmic paper. Heretofore writers of specifications seemed to pick the gravel thicknesses and sizes more or less out of the air. The formula at least provides for reasonable thicknesses of layers, $3\frac{1}{2}$ in., and provides in each layer that the largest diameter of stones be twice the smallest. The lowest layer of gravel must be somewhat arbitrarily chosen to provide adequate material to cover whatever form of underdrain system is used. In connection with design of pipe underdrain systems, there has been a tendency in recent years to use rather large pipe (4 in. in diameter and even up to 8 in. in diameter) with relatively large holes in the bottom ($\frac{1}{4}$ in. to $\frac{1}{2}$ in.). This has given

rise to the use of large stones and a thick layer sufficient to surround the pipe.

Carl Lauter in his comments lays great stress on the manner of placing gravel and sand. He points out that it is especially important to place the lower layers of gravel by hand in such manner as not to obstruct the flow of water from the holes in the underdrain laterals. None of the material, according to him, should be dumped into the filter. Instead he points out that the gravel and sand should be placed and not dropped and that they be spread with shovel and rake as smoothly as possible. If this is not done, hard spots are apt to develop.

Lauter believes that the engineer or the plant operator should have a good deal of latitude in specifying both the character of sand and gravel and the thickness of the layers. He believes that coarse sand should be of greater thickness than fine sand. He suggests that more might be said regarding the use of anthracite coal.

Thomas Riddick believes that the percentage of acid soluble material in the gravel is too high and suggests 2 per cent. Riddick feels that gravel of this specification can readily be obtained in the east. However, in the central west it is often necessary to use a gravel containing a number of limestone pebbles. If these pebbles are hard and well rounded they seem to perform satisfactorily as the gravel dissolves but slowly. Even sand in the central west contains a certain amount of calcareous material, which apparently does little harm provided it does not exceed 5 per cent.

Riddick also favors using gravel not larger than 2 in. in the bottom layer and he prefers a thicker layer of coarse gravel so as to extend about 4 in. above the top of the underdrains, assuming that they consist of pipe laterals. As part of the specifications he would require that "all gravel sizes up to ¼ in. be dumped on a 4-mesh-to-the-inch stiff screen (laid on canvas) before placing in the filter. This permits hand picking each bag separately for flat pieces which should be rejected even though it represents a loss of several per cent in weight."

Riddick inclines toward the use of sieve numbers rather than grain diameters as being more practical in specifying sand but favors listing sieve openings presumably as determined by calibration as specified.

H. E. Hudson Jr. indicates that sand dealers would prefer to have engineers specify the per cent by weight of diameters smaller than the 1 per cent, 10 per cent, and 60 per cent sizes only and believes these three separations are sufficient.

Prof. Charles Gilman Hyde made several suggestions for improved wording which were taken into account in the April 1942 draft of Proposed Tentative Specifications. Prof. Hyde has also informed the Chairman of improvements in sieve manufacture by the W. S. Tyler Co. The Committee Chairman has this to say:

"I have reviewed the latest catalog of W. S. Tyler & Company and note that the tolerances for sieve openings are still rather great, namely, plus or minus 5 per cent within the range of sieves ordinarily used in sand analysis. In other words, the situation has not changed materially since reports of the Committees on Filtering Material, 1921, 1924, and 1925. In the interest of conservatism, I think it would be better to adhere to the methods described in the *Water Works Practice Manual* (Appendix A).

"The question of using standard sieves without calibration comes up so frequently that I am of the opinion that the whole matter merits a review. Such a review, however, would require considerable research and therefore time does not permit of such a review by the present Committee. Perhaps a new Committee may be appointed for this specific purpose, or the existing Committee charged with the work. Our Committee is now working under positive instructions to present and recommend standard specifications at once so that they may be acted upon before the next Annual Meeting. A standard specification is not intended to be something unchangeable. I would think it appropriate to consider any phase of a standard specification in any year with a view to making modifications that will be in best accord with what is practicable and desirable."

The Committee Chairman also cites a communication from Mr. Cox as follows:

"I have also received a letter of comment from C. R. Cox, Secretary-Treasurer of the Water Purification Section. He expresses the belief that the Committee should be more specific in recognizing anthrafilt, or, let us say, crushed anthracite coal, as a

filtering material and setting forth its characteristics in comparison with sand. He also suggests that the Committee recognize the importance of greater depth of filtering material for coarse material as compared with fine. I think these points are well taken; but I have refrained from too much discussion of the theory and practice of filtration, because our Committee was instructed to prepare a standard specification and not a treatise on filtering material and the behavior of filter layers. If the specifications for the filtering material are otherwise acceptable, it seems to me that the designing engineer should be permitted considerable latitude in the design of the filter layer, including the choice of filtering material and the thickness of the filter layer."

Appendix D

Abstracted Comments of the Executive Committee of the Water Purification Division

The Executive Committee of the Water Purification Division has reviewed the "Proposed Tentative Standard Specifications for Filtering Materials. The following comments were made by members of the Water Purification Division Executive Committee:

"(1) The specifications should not be permitted to create the impression that exact compliance with the specifications is of great importance. . . . There is no ideal specification for sand and gravel that will be ideal for every plant or for any one plant for all time. . . . More attention should be given to the materials used and their source and physical composition and less to details of size, depth and sieving.

"(2) Table 2, dealing with the required depth of gravel in filter layers, should be eliminated insofar as the required depth of gravel is concerned and the table should be left blank so that the engineer or local water supply official may insert required values similar to Table 3.

"(3) The last part of Sec. 2.3 should be made to read '. . . not exceed 45 per cent and shall be obtained from a source approved by the engineer or purchaser.'

"(4) Probably a little more information could have been added about anthracite coal.

"(5) The report might be published in its present form, with the understanding that it would be revised and simplified at a later date."

Appendix E

Discussion by the Chairman of the Committee on Filtering Material

The Chairman of the Committee on Specifications for Filtering Materials has discussed these comments as follows:

"(1) In the discussions, it has been particularly emphasized that exact compliance with the specifications is not necessary and the engineer writing the specifications is given wide latitude in calling for any kind of filtering material that he desires. Acting under instructions, the Committee has prepared a specification as requested, with the understanding that a specification is desired primarily as a guide to engineers in writing specifications and which also would be of assistance to water works superintendents in ordering filtering materials. Unless the considerations involved in the purchase of any material are reduced to specification form, the prospective purchaser of material is not given much help. It is at least time-consuming and awkward for anyone purchasing filtering materials to do so on the basis of extended discussions and committee reports. It is not intended that the speci-

fications be final by any means. On the contrary, the specifications are subject to modification in the light of experience. The main purpose of the specifications is to set up a form that may be generally used in the interest of unifying practice and in the interest of economy.

"(2) There is no objection to leaving out the figures given in Table 2, dealing with the required depth of gravel in filters. The Committee inserted the figures primarily as a means of improving practice in this connection. The engineer, however, is at full liberty to change the gradation of supporting gravel if he has any reason for so doing.

"(3) [Referring to item (4) above] Several commentators have asked for more information about anthracite coal used as a filtering material. The criticism is valid to the extent that perhaps more should be said regarding the hardness, composition and specific gravity of anthracite coal. Sufficient material, however, was not at hand for doing this. It does not seem appropriate for the report to discuss anthracite coal as a filtering material. The choice as to sand or coal is up to the engineer.

EDITOR'S NOTE: All A.W.W.A. specification documents are required to be first published in *tentative* form.

This is done so that the field generally will have an opportunity to appraise the material, even though it has been approved in its tentative form by the Committee on Water Works Practice and by the Board of Directors. Objections to, and suggested changes in, tentative specifications, etc. are referred to the committee that developed the original document and evidence that such comments have been given adequate consideration is required before the document passes to the *standard* status.

American Water Works Association

Tentative Revision of

STANDARD SPECIFICATIONS

for

STEEL WATER PIPE OF SIZES UP TO BUT NOT INCLUDING 30 INCHES

The American Water Works Association has adopted and promulgates this "Tentative Revision of Standard Specifications for Steel Water Pipe of Sizes up to but Not Including 30 Inches." These specifications are based upon the best known experience and are intended for use under normal conditions. They are not designed for unqualified use under all conditions and the advisability of use of the material herein specified for any installation must be subjected to review by the engineer responsible for the construction in the particular locality concerned.

Approved as "Tentative Standard" by the Board of Directors of the A.W.W.A., April 25, 1940

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Tentative Revision of

STANDARD SPECIFICATIONS FOR STEEL WATER PIPE OF SIZES UP TO BUT NOT INCLUDING 30 INCHES

Section 4–1—General

Sec. 4–1.1—Scope

1.1.1. These specifications cover steel pipe intended for the conveyance of water, in sizes up to but not including 30 in. in diameter, and in random, double-random or specified laying lengths, straight sections or other special sections which are required for closures, curves, changes in alignment or grade to meet special conditions and with ends prepared for type of joint specified. The manufacturer or bidder shall state to the purchaser the type of pipe manufacture he proposes to use in the production of *mill* pipe or details of the procedure he proposes to use in the manufacture of *fabricated* pipe and special sections. This manufacturing procedure shall comply with the specifications given hereinafter unless otherwise agreed to by the engineer, purchaser or authorized inspector during the progress of the work.

1.1.2. The pipe covered by these specifications is manufactured by the following processes and in the nominal size ranges indicated in wall thicknesses and weights as covered by the tables which are Sec. A4–3.1 and A4–3.2 in the Appendix to these specifications.

(1) *Mill Pipe:*

Seamless, in sizes $\frac{1}{8}$ in. to 24 in. inclusive

Lap-welded, in sizes $1\frac{1}{4}$ in. to 20 in. inclusive

Butt-welded, in sizes $\frac{1}{8}$ in. to $3\frac{1}{2}$ in. od. inclusive

(a) *Electric-Welded:*

(i) Resistance-welded, in sizes $\frac{1}{4}$ in. to but not including 30 in.

(b) *Fusion-Welded:*

(i) Straight-seam, in sizes up to but not including 30 in.

(ii) Spiral-seam, in sizes up to but not including 30 in.

(2) *Fabricated Pipe:*

(a) *Electric-Fusion-Welded:*

(i) Straight-seam in sizes up to but not including 30 in.

(ii) Spiral-seam in sizes up to but not including 30 in.

Sec. 4–1.2—Supplementary Details to Be Provided by Purchaser

When purchasing pipe under these specifications, it will be necessary for the purchaser to make supplementary specific statements in his call for bids regarding the following:

1.2.1. Outside diameter.

1.2.2. Wall thickness.

1.2.3. Nominal weight per foot (uncoated).

1.2.4. When a particular class of pipe as listed in Table 1 in Sec. 4–2.1 is required, it shall be so stated; otherwise all classes shall be considered equal alternates.

1.2.5. Detailed description of the type of pipe ends with all drawings necessary to show shape, width, thickness, beveling or other details. Types of pipe ends are indicated in Sec. 4–2.7 of these specifications.

1.2.6. Lengths (random, double-random or specified).

1.2.7. The maximum number of longitudinal and girth seams permitted in each *fabricated* pipe section or the maximum number of lengths of *mill* pipe joined, in accordance with Sec. A4–2 in the Appendix to these specifications.

1.2.8. The maximum working water pressure, including water hammer allowance.

1.2.9. Detailed description and drawings of all special sections and special fittings, indicating, for each component part, the dimensions, the grade of material, the type of ends and the hydrostatic test pressure.

1.2.10. Kind of corrosion protection and whether it is to be applied in the field or at the mill (complete details of the coating to be applied, whether the pipe is to be completely coated from end to end, or if a certain specified distance at the end shall be left bare, or be oil-varnished, or painted with designated material either for field welding or to accommodate mechanical-type couplings, or to provide for other types of field joints).

Sec. 4–1.3—Definitions

Under these specifications, the definitions given in Sec. A4–1.1 of the Appendix of these specifications will apply.

Sec. 4–1.4—Inspection

1.4.1. If desired by the purchaser all work and material under these specifications may be inspected by his representative during all phases of manufacture and testing.

1.4.2. When the pipe sizes and wall thicknesses of *mill* pipe fall within the ranges commonly carried in mill stocks, the purchaser's inspector is authorized to accept the manufacturer's certified statement of the *hydrostatic* and *flattening* tests, which, if they have met the requirements of these specifications, shall be accepted in lieu of similar tests required by these specifications. All other tests shall be made as required by these specifications.

1.4.3. The purchaser may, however, elect to waive his inspection and accept instead a certified statement from the manufacturer that the required inspection and tests have been made.

1.4.4. When specifically requested the manufacturer shall also furnish a certified copy of laboratory tests, showing chemical and physical properties. The manufacturer shall notify the purchaser in advance of the production, so that the purchaser may arrange for mill and shop inspection.

1.4.5. The inspector may reject any or all pipe sections or special sections that do not meet the requirements of these specifications and the purchaser's supplementary instructions. It is understood that inspection, either by the purchaser's inspector or by the mill, shall not relieve the manufacturer of his responsibility to furnish material and to perform work in accordance with these specifications.

1.4.6. At all times while work on the contract of the purchaser is being performed, the inspector shall have free entry to all parts of the manufacturer's works which concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the pipe is being furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture prior to shipment and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Sec. 4–1.5—Inspectors

Inspectors shall be qualified by experience, shall be familiar with the class of pipe being purchased and the manufacturing processes for producing it and shall be capable of making such examinations and measurements as are necessary in determining whether or not the pipe being purchased conforms to the requirements of these specifications.

Sec. 4–1.6—Material and Workmanship

1.6.1. All material furnished by the manufacturer shall be of the specified quality. All work shall be done in a thoroughly workmanlike manner.

1.6.2. When the depth of defect is in excess of 12.5 per cent of the nominal wall thickness, such defect shall be considered injurious.

1.6.3. The welding of injurious defects in the plate or pipe wall, provided their depth does not exceed $\frac{1}{3}$ the specified wall thickness, will be permitted. Minor defects in the welds of electric-welded pipe, such as sweats or leaks, unless otherwise specified shall be repaired at the discretion of the manufacturer, with the approval of the inspector. Repairs of this nature shall be made by completely removing the defect, cleaning the cavity and then welding. The workmanship involved in the repair is subject to approval of the inspector. The hydrostatic test specified in Sec. 4–5.7 shall be made on the finished repaired pipe.

Sec. 4–1.7—Equipment—General Provisions

Manufacturer's equipment for all *fabricated* pipe, such as for welding, flame cutting and other operations, shall be of a standard and quality necessary to produce pipe meeting these specifications. Equipment, in general, shall be in good repair and shall be modern as judged by the standards of the industry.

Sec. 4–1.8—Drawings

Drawings referred to in these specifications shall be the purchaser's drawings.

Sec. 4–1.9—Testing

Pipe sections and special sections shall be tested as required herein.

Section 4–2—Description of Pipe

Sec. 4–2.1—Classes of Pipe

Classes of pipe covered by these specifications are given in Table 1, herewith.

TABLE 1

Classes of Pipe

Mill Pipe
Furnace-Welded
Lap-Welded
Butt-Welded
Electric-Welded
Resistance-Welded
Fusion-Welded
(a) Straight-Seam
(b) Spiral-Seam
Seamless
Seamless
Fabricated Pipe
Fusion-Welded
(a) Straight-Seam
(b) Spiral-Seam

Sec. 4–2.2—Chemical Properties of Steel

2.2.1. The steel for *mill* pipe shall be of good welding quality and may be made by the acid bessemer process or the open hearth process and shall conform to the requirements as to chemical composition given in Table 2, herewith.

TABLE 2

Chemical Properties

Element	Bessemer	Open Hearth
	per cent	*per cent*
Manganese, *not under*	0.30	0.30
Phosphorus, *not over*	0.11	0.045
Sulfur, *not over*	0.065	0.06

2.2.2. Steel plate for *fabricated* pipe shall conform to the chemical requirements of Grade B plates specified by A.S.T.M., A78 of latest revision (Low Tensile Strength Carbon-Steel Plates of Structural Quality for Welding), or as otherwise specified by the purchaser.

2.2.3. Steel sheets or coils used in *fabricated* pipe shall conform to the chemical requirements of Grade A material specified by A.S.T.M. A245 of latest revision (Light Gage Structural Quality Flat Hot-Rolled Carbon Steel) or as otherwise specified by purchaser.

2.2.4. The inspector may witness the manufacture and test of plates, sheets or coils used in *fabricated* pipe at the rolling mill and/or he may require that the manufacturer furnish him mill test reports on each heat from which the plates, sheets or coils are rolled. The inspector may require the manufacturer to furnish him with specimen plates or sheets of the steel that will be used in the manufacture of the pipe.

2.2.5. Specimen plates or sheets shall be of the size necessary to obtain the number of specimens required in the plate and/or sheet specifications and the tests of the specimen shall be made by the purchaser. If the specimens fail to meet the requirements of the applicable specifications under which they were manufactured, a second test shall be made. If all the specimens meet the requirements, the material shall be accepted, but if any of them fail to meet the requirements all material furnished under the same heat number shall be rejected. The manufacturer shall be charged, by the purchaser, for all expenses incurred in making a second test.

2.2.6. The inspector's approval of plates, sheets or coils shall be obtained before the manufacture of any pipe under these specifications.

Sec. 4–2.3—Check Analysis—Mill Pipe

2.3.1. Analysis of one length of pipe from each lot of 300 lengths, or fraction thereof, of each size under 4 in., and one length from each lot of 200 lengths, or fraction thereof, of sizes 4 in. to 20 in., inclusive, and one length from each lot of 100 lengths, or fraction thereof, of each size 22 in. and larger, inclusive, may be made by the inspector from the finished pipe. By agreement between the manufacturer and the inspector, however, the analysis may be taken from the skelp or plate and, when so taken, the number of analyses shall be determined in the same manner as when taken from the finished pipe.

2.3.2. If the analysis does not conform to the requirements specified, analyses of two additional lengths from the same lot shall be made, each of which shall conform to the requirements specified. If the result of both analyses of any lot does not conform to the requirement specified, the lot shall be rejected. However, the manufacturer may, at his option, submit each length of said lot for retest.

2.3.3. Drilling for analyses shall be taken from several points around each length of pipe or across each length of skelp or plate selected for test.

2.3.4. By agreement between the purchaser or his authorized inspector and the manufacturer, ladle analyses of each heat of steel may be furnished in lieu of check analyses as specified in Sec. 4–2.3.1.

Sec. 4–2.4—Physical Properties and Tests

2.4.1. The steel for *mill* pipe shall conform to the minimum longitudinal tensile properties as specified in Table 3, herewith.

TABLE 3

Property	Bessemer Lap-Welded or Butt-Welded	Open Hearth	
		Lap-Welded or Butt-Welded	Grade A Seamless or Electric Welded
Tensile Strength, *psi.*	50,000	45,000	48,000
Yield Point, *psi.*	30,000	25,000	30,000
Elongation, *in 8 in.* %	18	22	—
Elongation, *in 2 in.* %	—	—	30

2.4.2. Steel plate used in *fabricated* pipe shall conform to the physical properties specified for Grade B plates called for by A.S.T.M. A78 of latest revision (Low Tensile Strength Carbon-Steel Plates of Structural Quality for Welding), or as otherwise specified by the purchaser.

2.4.3. Steel sheets or coils used in *fabricated* pipe shall conform to the physical properties of Grade A material specified by A.S.T.M. A245 of latest revision (Light Gage Structural Quality Flat Hot-Rolled Carbon Steel), or as otherwise specified by the purchaser.

2.4.4. Specimens cut longitudinally from the pipe shall be acceptable for the tension test. The tension test specimen shall consist of a strip cut from either end of the pipe. The tension test specimens for *fabricated* pipe may be taken from the skelp or plate.

2.4.5. The test specimens for *mill* pipe under 4 in., not pulled in full cross-section, shall have a strip width within the gage length of 1 in. and not

4 in. and over shall have a strip width within the gage length of 1½ in. and not flattened between gage marks. When grips with suitable curved faces are not available, the ends of the specimens may be flattened cold. The strip shall have a gage length of 2 in. or 8 in., as called for in Table 3. The sides shall be parallel between gage marks. The specimens from welded pipe shall be taken from a point approximately 90 deg. from the weld. The specimen taken from the skelp or plate shall be cut longitudinally, with the longitudinal axis located approximately midway between the center and the edge of the skelp or plate.

2.4.6. The yield point shall be determined by the drop of the beam or halt of the gage of the testing machine, by dividers or other approved method.

NOTE: For the required number of tension tests, hydrostatic tests and physical tests of welded joints, *see* Sec. 4–5—Tests.

Sec. 4–2.5—Diameter of Pipe

2.5.1. The diameter of pipe shall be as specified in the request for bids and shall be designated by outside diameter. Sections A4–3.1 and A4–3.2 in the Appendix to these specifications are lists of sizes and wall thicknesses of *mill* and *fabricated* pipe, respectively.

2.5.2. It shall be understood that the specified diameter is subject to the tolerances given in these specifications.

Sec. 4–2.6—Length of Sections

2.6.1. Straight pipe section shall be of the length specified and subject to length tolerances, in accordance with these specifications.

2.6.2. Length of sections of *mill* pipe shall be designated by random lengths, double-random lengths or by definite dimension (specified length).

2.6.3. Length of sections of *fabricated* pipe shall be designated by definite length dimension (specified length).

2.6.4. When "specified lengths" are ordered, the purchaser shall have the right to order additional shorter lengths, other than full length sections, which may be required for closures or proper location of any special section. Lengths of special sections shall be specified by the purchaser.

2.6.5. For sizes up to and including 24 in. in outside diameter, random lengths (approximate average, 20 ft.) of lap-welded, electric-welded and seamless pipe shall be not less than 16 ft. Unless otherwise specified, 5 per cent of lengths may be furnished 12 to 16 ft.

2.6.6. For sizes up to and including 24 in. in outside diameter, double-random lengths (approximate average 40 ft.) shall be not less than 32 ft. Unless otherwise specified, 5 per cent of lengths may be furnished 24 to 32 ft. Double-random lengths may be furnished in single lengths or by welding together two random lengths in accordance with Sec. A4–2 in the Appendix to these specifications.

2.6.7. For sizes over 24 in. in outside diameter, electric-welded *mill* pipe shall be furnished in lengths approximately 30 ft. or over. Unless otherwise specified, 5 per cent of the lengths may be furnished 24 to 30 ft.

Sec. 4–2.7—Ends of Sections

Ends of pipe sections and special sections shall be specified by the purchaser and shall be of any of the following types, more fully described in Sec. 4–3.9.

2.7.1. Ends for mechanically coupled field joints

2.7.2. Ends with slip joints for field welding

2.7.3. Plain ends or beveled ends for field butt welding

2.7.4. Plain ends fitted with butt straps for field welding

2.7.5. Beveled ends fitted with butt straps for field welding (This applies to sizes 24 in. and over.)

2.7.6. Ends for riveted field joints

2.7.7. Bell and spigot ends for calked joints

2.7.8. Plain ends fitted with flanges

2.7.9. Taper ends for driven field joints.

Section 4–3—Fabrication

Sec. 4–3.1—Longitudinal Seams

The longitudinal seams of electric-resistance-welded pipe, of electric-fusion-welded *mill* pipe, whether straight-seam or spiral-seam, and of *fabricated* pipe shall be butt welded. The purchaser may specify the maximum number of longitudinal seams to be permitted in each section of *fabricated* pipe.

Sec. 4–3.2—Girth Seams

3.2.1. Shop girth seams shall be butt welded or lap joint welded. The purchaser may specify the maximum number of girth seams to be permitted in each section of *fabricated* pipe.

3.2.2. Requirements for circumferential welding of straight lengths of *mill* pipe shall be in accordance with Sec. A4–2 in the Appendix of these specifications.

Sec. 4–3.3—Special Sections

3.3.1. Curves, tees, branches and other sections required for changes of alignment or grade shall be designed in accordance with the purchaser's requirements or fabricated in accordance with the drawings. When such details are not specified, the angular change for welded plate specials shall not exceed 22½ deg. for cuts for curves or 45 deg. for branches for wyes.

3.3.2. Short straight transitional and tapered sections shall have the required type of ends as specified by the purchaser.

Sec. 4–3.4—Adapters

Saddles, nozzles or other fittings intended for connection to other pipelines and structures shall be of the required material and fabricated in accordance with detailed description and drawings furnished by the purchaser or fabricated in accordance with the drawings.

Sec. 4–3.5—Cutting

All edges cut to size shall be uniform and smooth. Those edges to be welded, that are prepared by flame cutting, shall be free from scale and slag accumulations.

Sec. 4–3.6—Shaping of Plate Edges for Fabricated Pipe

3.6.1. Edges of plates to be joined by an automatic welding machine shall be formed to the shape required for the particular welding process and automatic welding machine to be employed in carrying out the agreed procedure. Edges of plates to be joined by manual welding shall be formed to the shape required by the purchaser or in accordance with the drawings. The

resulting edges for welding shall be uniform throughout the entire length of the plate and shall be to a straight line.

3.6.2. Special sections having abutting plates of different thicknesses shall have the heavier plate sufficiently beveled so that the apex of the weld groove shall correspond with that of the lighter plate.

Sec. 4–3.7—Operations on Fabricated Pipe

All lap breaking, rolling, cleaning of plate surfaces to be welded and fitting-up operations, as well as the qualification of the welding operators, welding procedure, automatic welding, manual welding and correction of welds in *fabricated* pipe, shall be in accordance with requirements of the A.W.W.A. 7A.3 of latest revision (Standard Specifications for Electric-Fusion-Welded Steel Water Pipe of Sizes 30 Inches and Over).

Sec. 4–3.8—Rounding up of Pipe Sections

Reshaping pipe after it is manufactured shall be done by rerolling or by pressure. Reshaping of pipe by excessive hammering or dropping will not be permitted.

Sec. 4–3.9—Preparation of Ends of Sections

3.9.1. *Ends for Mechanically Coupled Field Joints:* Ends for mechanically coupled field joints shall be as specified by the purchaser and shall be plain, grooved or banded. The outside of plain-end pipe shall be free from visible surface defects and shall have the longitudinal or spiral weld beads ground to plate surface for a distance of 8 in. back from the ends. Grooved or banded ends shall be prepared to fit the type of mechanical coupling to be used.

3.9.2. *Ends With Slip Joints for Field Welding:* Bell ends shall be pressed or rolled to the required shape without hammering. Spigot ends shall be shaped in or over a die. Any longitudinal weld beads on the inside of the bell end and on the outside of the spigot end on each section of *fabricated* pipe shall be ground to plate surface for the slip joint. The inside edge of the bell end and the outside edge of the spigot end shall be scarfed or lightly ground sufficiently to remove the sharp edges or burrs in the end of the pipe sections.

3.9.3. *Ends Plain or Beveled for Field Butt Welding:* Ends of pipe sections, when thickness is $\frac{1}{4}$ in. or greater, required for field butt welds, either with or without backing-up strips or chill rings, shall be beveled. The standard bevel for ends for field welding is 30 deg., measured from a line drawn perpendicular to the axis of the pipe. If other than this standard bevel is desired, the angle thus measured should be so specified.

3.9.4. *Plain Ends Fitted With Butt Straps for Field Welding:* Plain ends of pipe sections fitted with butt straps for field joints shall comply with the details shown on the drawings. Butt straps shall be of the same thickness as the corresponding pipe sections, shall be of the required width, shall be rolled to fit the outside diameter and shall be welded to the pipe section. Longitudinal or spiral weld beads on the outside of the plain end shall be ground to plate surface a sufficient distance from the end. The inside edge of the butt strap and the outside edge of the adjacent pipe length shall be

ground or sufficiently scarfed to remove sharp edges or burrs.

3.9.5. *Beveled Ends of Pipe Sections 24 Inches and Over in Diameter, Fitted With Butt Strap for Field Joints:* Beveled end of pipe sections fitted with butt strap for field joints shall comply with Sec. 4–3.9.4. except that the inside ends shall be beveled in accordance with Sec. 4–3.6 or as otherwise specified, and the butt strap may be thinner than the pipe wall, but not less than $\frac{1}{8}$ in. thick.

3.9.6. *Ends for Riveted Field Joints:* Ends for riveted field joints shall be as specified by the purchaser and shall be prepared for bumped joints, butt-strap joints or lap joints, the latter formed by using tapered pipe sections or inside and outside pipe sections. Plate edges at ends of pipe shall be planed or bevel-sheared, suitable for field calking. Rivet holes shall be accurately spaced as required and shall be drilled or sub-punched and reamed $\frac{1}{16}$ in. larger than the nominal size of the rivet. Holes shall be free from burrs and torn or damaged edges.

3.9.7. *Bell and Spigot Ends for Calked Joints:* Bell ends may be pressed or rolled or fabricated hot or cold from plate into the required shape without hammering. Spigot ends shall be formed to the required dimensions. Longitudinal or spiral weld beads on the inside of the bell end and on the outside of the spigot end on each section of pipe shall be ground to plate surface for the joint.

3.9.8. *Plain Ends Fitted With Flanges:* Ends to be fitted with flanges shall have the longitudinal or spiral weld beads on the pipe ground to plate surface for a distance of at least 1 in. greater than the hub depth of the flange to be attached. Flanges shall be of the type, and welded on the pipe as, specified or shown on the drawings.

3.9.9. *Tapered Ends for Driven Field Joints:* Ends shall be prepared to produce a tight field driven joint.

Section 4–4—Tolerances

Sec. 4–4.1—Mill Pipe Tolerances

4.1.1. *Diameter:* The outside diameter of pipe shall not vary more than 1 per cent over or under the size specified, except that the diameter at ends shall be as specified in Sec. 4–4.1.6, paragraph 3.

4.1.2. *Wall Thickness:* The minimum wall thickness at any point shall be not more than 12.5 per cent under the nominal wall thickness specified.

4.1.3. *Weight:* (1) The weight of any length shall not vary more than 5.0 per cent under or 10.0 per cent over that specified, but the carload weight shall not be more than 1.75 per cent under the nominal weight.

(2) Unless otherwise agreed upon, pipe sections shall be weighed separately.

4.1.4. *Length:* (1) For all classes of pipe, when ordered to a specified length, the tolerance shall be $\pm \frac{1}{8}$ in.

(2) For specials such as elbows, wyes, tees, reducers, closure pieces, etc., the length tolerance shall be as agreed upon by the purchaser and manufacturer.

4.1.5. *Straightness:* (1) Finished pipe which is not spun-enamel-lined by the centrifugal casting process shall be commercially straight.

(2) When finished pipe is to receive a spun-enamel lining applied by

the centrifugal casting process and the spinning equipment does not hold pipe in axial alignment, any free pipe sections with faulty alignment exceeding $\frac{1}{8}$ in. for each 10 ft. in length from a line parallel to the axis of the pipe shall be straightened.

4.1.6. *Ends:* (1) Plain end pipe for use with the mechanical type coupling shall have square cut or beveled ends and the inside and outside edge burrs shall be removed. The pipe shall also be sufficiently free from indentations, projections or roll marks for a distance of 8 in. from each end to make a tight joint with the rubber gasket.

(2) Beveled end pipe for field welding shall be beveled on the outside or on the inside, as specified, to an angle of 30 deg., with a plus tolerance of 5 deg. and no minus tolerance. The average width of flat (root face) at the end of the pipe shall be $\frac{1}{16}$ in. with a tolerance $\pm \frac{1}{32}$ in. When pipe ends are ordered beveled to a 30-deg. angle, or any other angle, it should be understood that the angle is measured from a line drawn perpendicular to the axis of the pipe. This means that a greater amount of material is removed with a 60-deg. angle than with a 30-deg. angle.

(3) All plain end pipe intended for either the mechanical type coupling (compression type) or for field welding on sizes $10\frac{3}{4}$ in. in outside diameter and under shall be not more than $\frac{1}{64}$ in. smaller than the specified outside pipe diameter for a distance of 8 in. from each end, as determined by a steel tape circumferentially applied, and shall permit the passing, for a distance of 8 in. of a ring gage which has a bore $\frac{1}{16}$ in. larger than the specified outside diameter of the pipe. Sizes 12 in. and larger in outside diameter shall not be more than $\frac{1}{32}$ in. smaller than the specified outside pipe diameter for a distance of 8 in. from each end, as determined by a steel tape circumferentially applied, and shall permit the passing, for a distance of 8 in. of a ring gage which has a bore of $\frac{3}{32}$ in. larger than the specified outside diameter of the pipe.

(4) Ends for other type mechanical couplings shall have tolerances within the limits required by the manufacturer of the type of coupling to be employed.

(5) Tolerances for other types of joints shall be in accordance with Sec. 4–4.2, where applicable.

Sec. 4–4.2—Fabricated Pipe Tolerances

4.2.1. *Diameter, Ends:* (1) Each section of pipe shall be accurately measured with a steel tape and shall not exceed the tolerances set forth below; provided, however, that such tolerances do not interfere with the making of the joints.

(2) For a distance of not less than 8 in. from the ends, the outside circumference of pipe, with the following types of ends, shall be not more than $\frac{1}{16}$ in. smaller, nor more than $\frac{1}{8}$ in. greater, than the outside circumference computed from the specified nominal inside diameter and the specified plate thickness:

(a) Plain ends of slip joint pipe for field welding
(b) Plain ends with butt straps for field welding
(c) Beveled ends fitted with butt straps for field welding
(d) Both ends of inside section of inside and outside pipe sections and the smaller end of tapered section for lap-riveted field joints
(e) Plain ends fitted with flanges.

(3) Ends for mechanical couplings shall have tolerances within the limits required by the manufacturer of the type of coupling to be employed.

(4) For a distance of not less than 8 in. back from the ends, the inside circumference of pipe, with the following type of ends, shall be not more than $\frac{1}{16}$ in. smaller, nor more than $\frac{1}{8}$ in. greater, than the inside circumference computed from the nominal inside diameter:

(a) Ends plain or beveled for field butt welding
(b) Bumped ends for riveted field joints
(c) Plain end of bell and spigot pipe for calked joints
(d) Ends for riveted field joints (tolerance for tapered pipe to apply at the smaller end only).

(5) The inside diameter of the bell of slip joint pipe for field welding shall be between $\frac{1}{32}$ in. and $\frac{1}{16}$ in. greater than the outside diameter of the plain end. The inside diameter of the outside section of inside and outside pipe sections and the inside diameter of the larger end of tapered sections for lap-riveted field joints shall be between $\frac{1}{16}$ in. and $\frac{1}{8}$ in. greater than the outside diameter of the inside section or smaller end of the tapered section; such outside diameter shall be determined from the nominal inside diameter and the specified plate thickness.

(6) The out-of-roundness of pipe ends at the fabricator's plant, when measured on any diameter, shall be within limits consistent with the type of field joint specified and the type of corrosion protection to be employed.

(7) The ends of all pipe sections shall not vary more than $\frac{1}{8}$ in. at any point from a true plane at right angles to the axis of the pipe.

4.2.2. *Wall Thickness:* Steel plate shall be ordered to thickness, with a maximum allowable variation of $\frac{1}{100}$ in. under the specified thickness.

Steel sheets or coils shall be ordered to thickness and the tolerances for all sheets and coils shall not exceed the maximum permissible variation as given in A.S.T.M. A245 of latest revision.

4.2.3. *Length:* Length of straight pipe shall not vary from the specified length by more than ± 2 in. Length of special sections shall not vary from specified length by more than $\pm \frac{1}{8}$ in.

4.2.4. *Straightness:* (1) Finished pipe which is not spun-enamel-lined by the centrifugal casting process shall be commercially straight.

(2) When finished pipe is to receive a spun-enamel lining applied by the centrifugal casting process and the spinning equipment does not hold pipe in axial alignment, any free pipe sections with faulty alignment exceeding $\frac{1}{8}$ in. for each 10 ft. in length from a line parallel to the axis of the pipe shall be straightened.

Section 4–5—Tests

Sec. 4–5.1—Weld Test Specimens

5.1.1. Transverse weld tests required on electric-welded pipe are for the purpose of determining minimum tensile strength only and shall not be required on sizes under 8 in. in outside diameter.

5.1.2. For transverse weld tests, the test specimen shall consist of a strip cut transversely from the end of the pipe, with a width of 1½ in. with the weld located about the middle of its length and machined parallel for a length of 2 in. Specimens may be flattened hot or may be flattened cold and normalized before testing. The tensile strength across the weld shall not be less than the minimum tensile strength of the grade of steel ordered.

5.1.3. For *fabricated* pipe, the transverse weld test specimens for electric-fusion-welded pipe may be taken from a welded test plate (or coupon). The welded test plate (or coupon) shall be cut from steel of the same specifications and thickness as the pipe, shall have edges prepared for welding, and shall then be attached at one end of the longitudinal joint of the pipe, so that the edges to be welded in the test plate form a continuation of, and duplication of, the corresponding edges of the longitudinal joint. In this case, the weld metal shall be deposited in the plate continuously, with the weld metal deposited in the longitudinal joint.

5.1.4. Where specimens, by agreement between the inspector and the manufacturer, are taken from points other than the ends of the pipe, the openings resulting from removal of test specimens shall be patched in a manner approved by the inspector.

5.1.5. All specimens shall be tested at room temperature.

Sec. 4–5.2—Flattening Tests—Mill Pipe

5.2.1. The crop end, or a ring 3 in. in width, cut from each end of each length of lap-welded or electric-resistance-welded pipe, shall be flattened between parallel plates, with the weld at the point of maximum bending, until opposite walls of the pipe meet. Specimens for flattening tests shall be smooth on the ends and free from burrs. No opening in the weld shall take place before the distance between the plates is less than ⅔ of the original outside diameter of the pipe. No cracks or breaks in the metal, elsewhere than in the weld, shall occur before the distance between the plates is less than ⅓ of the original outside diameter of the pipe. Evidence of laminations or burnt material shall not develop during the entire flattening process. If any section fails to meet these requirements, another piece may be cut. If the second test fails, additional tests may be made until the requirements are met or the length rejected, except the finished pipe shall not be shorter than 80 per cent of its length after the first crop was cut. Precautions shall be taken so that crop ends or rings can be identified with respect to the lengths from which they are cut.

5.2.2. For butt-welded pipe over 2 in. in nominal diameter, a section of pipe 4 in. to 6 in. long, cut from each lot of 100 lengths or less, of each size, shall be flattened between parallel plates, with the weld located 45 deg. from the point of maximum bending,

until the distance between the plates is 60 per cent of the outside diameter of the pipe, without developing cracks.

Sec. 4–5.3—Bend Tests

5.3.1. The bend test specimen, 1 in. wide by 6 in. long, cut from each test length of *electric-fusion-welded* pipe, sizes 8 in. and over in outside diameter, shall be taken across the weld and shall stand being bent cold through 180 deg. around a pin, the diameter of which is equal to $4\frac{1}{2}$ times the thickness of the plates, without developing cracks. In making the bend test, the side of the specimen representing the inside of the pipe shall be placed next to the pin. The bend test specimen shall have the protruding portions of the weld, both inside and outside the pipe, removed by machining or grinding.

5.3.2. For *butt-welded* pipe 2 in. or under in diameter, a sufficient length of pipe shall withstand being bent cold through 90 deg. around a cylindrical mandrel, the diameter of which is 12 times the nominal diameter of the pipe, without developing cracks at any portion and without opening the weld.

Sec. 4–5.4—Number of Tests

5.4.1. One longitudinal tension test specified in Sec. 4–2.4 shall be made on one length of pipe from each lot of 300 lengths, or fraction thereof, of each size 6 in. and under (nominal size), from each lot of 200 lengths, or fraction thereof, of each size, 8 in. (nominal size) to 20 in. inclusive, and from each lot of 100 lengths or fraction thereof, of each size 22 in. and larger.

5.4.2. In addition to the above, one transverse weld test on electric-welded pipe specified in Sec. 4–5.1 and on electric-fusion-welded pipe one bend test specified in Sec. 4–5.3 may be made on one length from each lot of 200 lengths, or fraction thereof, of sizes 8 in. to 20 in., inclusive, and on one length from each lot of 100 lengths, or fraction thereof, of each size 22 in. and larger.

5.4.3. When taken from the skelp or plate or welded test plate (coupon), the number of tests shall be determined in the same manner as when taken from the finished pipe.

Sec. 4–5.5—Special Weld Tests

When *fabricated* steel pipe is furnished under these specifications for working pressures exceeding 200 psi., the additional tests of welds and welded joints as required by Sec. 3–5—Tests of A.W.W.A. 7A.3 of latest revision (Standard Specifications for Electric-Fusion-Welded Steel Water Pipe of Sizes 30 Inches and Over) will be made, if specifically requested by the purchaser in the call for bids.

Sec. 4–5.6—Retests

5.6.1. If the results of the physical tests of any lot do not conform to the requirements specified, retests of two additional lengths of pipe or pieces of skelp or plate from the same lot shall be made, each of which shall conform to the requirements specified. If the results of both retests of any lot do not conform to the requirement specified, the lot shall be rejected. However, the manufacturer may, at his option, submit each length of said lot for retest.

5.6.2. If the percentage of elongation of any longitudinal tension test specimen is less than that specified and any part of the fracture is outside the middle third of the gage length of an 8-in. specimen or more than $\frac{3}{4}$ in. from the center of the gage length of a 2-in.

specimen, as indicated by scribed scratches marked on the specimen before testing, the specimen may be discarded and another substituted.

5.6.3. If any test specimen shows defective machining or develops flaws not associated with the welding, it may be discarded and another specimen substituted.

Sec. 4–5.7—Hydrostatic Test of Pipe

5.7.1. All straight pipe shall be tested at the mill or shop to the hydrostatic pressures specified in Sec. A4–3.1 for *mill* pipe and Sec. A4–3.2 for *fabricated* pipe as given in the Appendix to these specifications, which pressures shall be maintained for not less than 5 sec. In this test no hammering will be required.

5.7.2. *Sizes Not Listed:* For diameters and wall thicknesses not listed, the test pressure shall be proportional to the pressures specified in Sec. A4–3.1 for *mill* pipe and Sec. A4–3.2 for *fabricated* pipe as given in the Appendix to these specifications, which pressures shall be maintained for not less than 5 sec.

5.7.3. *Bends, Branch Connections and Special Sections:* Bends, branch connections and other special connections made in accordance with the requirements of Sec. 4–3.7 by certified welding operators from tested pipe shall not be subjected to a hydrostatic test pressure. All other bends, branch connections and other special connections not fabricated from tested pipe shall be subjected to a hydrostatic test pressure specified by the purchaser.

NOTE: It is recommended that the maximum test pressure for all bends, branch connections, and special sections shall not exceed 1½ times the working water pressure.

5.7.4. *Procedure for All Welded Pipe:* All welded seams shall be inspected for leaks and each leak shall be marked plainly. Any section showing more than one leak for each 5 ft. of welded seam or more than 2½ per cent of the total length of welded seam will be rejected. Closing leaks by means of calking tool will not be permitted. The sections showing less than one leak for each 5 ft. of welded seam and not more than 2½ per cent of the total length of the welded seam shall have the leaks repaired by chipping the weld and rewelding by hand, after which the pipe shall be retested hydrostatically in a duplicate manner.

On a retest, the pipe section shall show no leaks in the welded seams and, if any appear, the section will be rejected. Accepted pipe sections shall be stamped after test by the inspector with some legible mark of identification.

Section 4–6—Cleaning and Coating Pipe Surfaces

Sec. 4–6.1—Cleaning

If not otherwise specified by the purchaser, each section of pipe shall be thoroughly cleaned, both inside and outside, of loose mill scale, paint, grease, oil and other foreign substance. The method and material used in cleaning shall be approved by the inspector.

Sec. 4–6.2—Coating of Pipe

It is recommended that all pipe shall be properly coated and the material used and the procedure followed in priming and enameling or painting of surfaces of pipe sections shall be in accordance with the purchaser's supplementary specification based on

A.W.W.A. 7A.6 of latest revision (Standard Specifications for Coal-Tar Enamel Protective Coatings for Steel Water Pipe of Sizes up to but Not Including 30 Inches), selected with respect to the conditions encountered.

Section 4–7—Delivery

Sec. 4–7.1—Marking

7.1.1. Each length of uncoated *mill* pipe shall be legibly marked either by stenciling, stamping or rolling to show by whom manufactured, the class of pipe, the outside diameter, the nominal weight per foot or wall thickness, the overall length, the test pressure and any additional marks or symbols specified by the purchaser.

7.1.2. In the case of coatings applied to *mill* pipe at the mill, the manufacturer's name, weight per foot or wall thickness, overall length and class of pipe shall be legibly applied by stenciling after coating.

Sec. 4–7.2—Delivery of Pipe

When so specified, pipe sections and special sections shall be delivered in the order required and shall be loaded as required by the purchaser.

APPENDIX

Section A4–1—Definitions

The following definitions, arranged alphabetically, will apply to the American Water Works Association Standard Specifications for Steel Water Pipe of Sizes up to but Not Including 30 Inches:

Bessemer Steel: Steel made by the acid bessemer process.

Butt Weld: A weld whose throat lies in a plane disposed approximately 90 deg. with respect to the surfaces of at least one of the parts joined. The size of a butt weld is expressed in terms of its net or unreinforced throat dimensions in inches. A double-welded butt joint is one in which the filler metal is added to both sides. A single-welded butt joint is one in which the filler metal is added to one side only.

Butt-Welded Pipe: Furnace welded pipe made by drawing heated skelp through a funnel-shaped welding die or through welding rolls which bend the skelp into tubular form, with the edges brought together with sufficient pressure to weld them. Butt-welded pipe is made in sizes $\frac{1}{8}$ in. to $3\frac{1}{2}$ in. od inclusive.

Check Analysis: Refers to the chemical analysis taken from the skelp or plate or finished pipe.

Class of Pipe: The designation of pipe in accordance with method of manufacture. See Table 1 in Sec. 4–2.

Coupon (Weld Coupon): A pair of test plates of specified dimension made from metal of the same specifications and thickness as the pipe wall, prepared for welding, attached to a pipe shell being welded at the end of a longitudinal joint so that the edges to be welded in the test plates are a continuation of, and duplication of, the

corresponding edges of the longitudinal joint. The pair of plates is then made into a single weld test specimen by having the weld metal deposited in the test plates continuously with the weld metal deposited in the longitudinal joint and by the same process, procedure and technique.

Double-Length Welded Pipe: Two single-random lengths welded together to make a double-random length.

Double-Random Lengths: The length of a pipe in its finished condition as supplied when double-length pipe of no definite length is specified, subject to limitations stated in Sec. 4–2.6.

Fabricated Pipe: Pipe made of individual curved plates formed to circles or parts of circles and joined by fusion welding to produce cylinders which in turn may be joined end to end to achieve pipe sections of various lengths.

Fillet Weld: A weld of approximately triangular cross-section whose throat lies in a plane disposed approximately 45 deg. with respect to the surfaces of the parts joined. The size of a fillet weld is expressed in terms of the width, in inches, of one of its adjacent fused legs, the shorter if unequal.

Flame Cutting: The process of severing metal by means of a gas flame.

Fusion Welding: The process of welding metals in the molten, or molten and vaporous state, without the application of mechanical pressure or blows.

Girth Seam: A circumferential welded seam lying in one plane, used to join lengths of straight pipe or to join pieces of mitered pipe to form fabricated elbows or turns.

Grade of Material: The designation of material as to chemical analysis or physical properties.

Inspector: The word "inspector," as used herein, means the inspector or engineer of the purchaser or their respective assistants properly authorized and limited to the particular duties entrusted to them.

Ladle Analysis: The chemical analysis taken at the time the steel is being cast into ingots.

Lap-Welded Pipe: Furnace-welded pipe made from skelp with scarfed or beveled edges, heated, bent to tubular form and welded to uniform wall thickness with the edges overlapping.

Large-Diameter Pipe: Pipe 14 in. and over. Size designations refer either to actual outside diameter or actual inside diameter and pipe is specified by outside diameter and wall thickness or inside diameter and wall thickness. Nominal weight per linear foot should be given.

Large-Outside-Diameter Pipe: Pipe 14 in. to 30 in., inclusive. Size designations refer to actual outside diameter. This pipe is specified by outside diameter, wall thickness and nominal weight per linear foot.

Manufacturer: The word "manufacturer," as used herein, means the person, firm or corporation furnishing pipe, pipe joints, pipe fittings and pipe coatings, exclusive of any erection or installation requirements or other field work.

Mill Pipe: Pipe made from hot or cold skelp, plate or solid rounds by common tube mill methods wherein the process is usually more or less continuous and the pipe itself moves during the making and finishing operations.

Nominal Outside Diameter: Refers to the commercial name or given dimension for pipe in sizes up to 12 in.,

as distinguished from the actual or real dimension.

Nominal Size: Refers to the commercial name or given dimension for pipe in sizes up to 12 in., as distinguished from the actual or real dimension.

Nominal Wall Thickness: Refers to the theoretical wall thickness of average wall pipe which has a commercial under-tolerance.

Nominal Weight per Foot (for Uncoated and Unlined Pipe): Refers to the theoretical weight per foot, as shown in published tables, as distinguished from the actual weight per foot of the finished pipe.

Open Hearth Steel: Steel made by the open hearth process.

Plain End Pipe: Pipe cut off to random or exact lengths, but not threaded. It is not beveled unless so specified.

Purchaser: The word "purchaser," as used herein, means either person, firm, corporation or governmental subdivision entering into a contract or agreement for the purchase of any materials or work to be performed under these specifications.

Random Length: The length of a pipe, in its finished condition, as supplied when a definite length is not specified but subject to limitations stated in Sec. 4–2.6.

Resistance-Welded Pipe: Pipe made by a series of operations in which the flat-rolled material is cold-shaped into tubular form, and the union of the seam effected by the application of heat and pressure. The welding heat is generated at the seam by resistance to the flow of an electric current.

Root: The word "root" as used herein in describing fusion-welding procedure means the zone at the bottom of the cross-sectional space provided to contain the deposited filler metal.

Seal Weld: A continuous weld primarily intended to secure tightness.

Seam: The continuous line of fusion achieved by any welding process.

Seamless Pipe: Pipe without seams made from solid ingots, blooms, billets or round bars which have been hot-pierced and then brought to the desired size by either hot-rolling or hot-drawing or a combination of both.

Specified Lengths: Sections of finished pipe whose length dimensions do not vary from a fixed figure specified by the purchaser by more than the length tolerance.

Spiral-Seam Fusion-Welded Pipe: Pipe in which the line of the fusion seam forms a helix on the barrel of the pipe, or forms a part helix.

Standard Pipe: Pipe $\frac{1}{8}$ in. to 12 in., inclusive, which has a definite thickness corresponding to a given diameter, and is specified by its nominal diameter. Standard pipe may be seamless or welded and is listed in three schedules by thickness; standard weight, extra strong and double extra strong.

Straight-Seam Fusion-Welded Pipe: Pipe in which the line of the fusion seam parallels the axis of the pipe.

Strength Weld: A weld designed to have a predetermined strength and primarily intended to secure a mechanically strong joint. The weld may be continuous or intermittent.

Throat: The thickness of deposited weld metal not including reinforcing, along a straight line passing through the root.

Weld: A localized consolidation of metals.

Section A4–2—Requirements for Circumferential Welding of Straight Pipe Lengths*

Sec. A4–2.1—Method

Welding of any type generally recognized as sound commercial practice shall be permitted.

Sec. A4–2.2—Workmanship

2.2.1. The ends of the pipe to be welded together shall be prepared in accordance with the requirements of the process used. The completed length shall be straight, within limits recognized by these specifications.

2.2.2. All welds shall be marked so as to identify the welders.

2.2.3. The weld shall have a substantially uniform cross-section throughout the circumference of the pipe. The crowned surface shall at no point be below the outside surface of the parent metal, nor shall the crown at any point rise above the outside surface of the pipe more than 50 per cent of the thickness of the pipe. Finished lengths of mill pipe, when so stipulated, shall permit the passage of a drift $\frac{1}{8}$ in. less than the nominal inside diameter of the pipe on sizes up to but not including $8\frac{5}{8}$ in.; $\frac{5}{32}$ in. on sizes $8\frac{5}{8}$ in. to 14 in., inclusive; and $\frac{3}{16}$ in. on sizes 16 in. to 20 in., inclusive.

Sec. A4–2.3—Tension Tests

2.3.1. The test specimen taken across the circumferential weld, but not nearer than 90 deg. to the longitudinal weld, shall show a tensile strength at room temperature not less than the minimum tensile strength specified in Table 3 in Sec. 4–2 for the class of pipe in question. The openings resulting from removal of test specimens shall be patched in a manner approved by the inspector.

2.3.2. The test specimen shall be prepared and tested in the same manner as prescribed in Sec. 4–5.1 of these specifications.

Sec. A4–2.4—Number of Tests

One tensile test shall be made on one of each 25 welds or not less than one test per order when the total welds in the order are less than 25.

Sec. A4–2.5—Retests

If any specimen fails to develop the tensile strength specified in Table 3 in Sec. 4–2 for the class of pipe in question, the pipe length from which it was taken shall be rejected and retests on current work from two additional lengths welded by the same welder shall be made, both of which shall meet the specified tensile strength requirement. If either of these tests fails, all of the work performed by the said welder in that particular lot shall be rejected.

Sec. A4–2.6—Repairing Defects

Minor defects in circumferential welds, such as sweats or leaks, may be repaired when and as specified in Sec. 4–5.7.4.

* Note Sec. 4–3.2.

Section A4–3—Physical Data on Steel Pipe for Underground Water Service

Sec. A4–3.1—Mill Pipe

Nominal Size	Outside Diam.	Wall Thickness (Decimal)	Weight per Linear Foot	Working Pressure (Safety Factor of 4.0)		Approximate Ultimate Bursting Pressure		Test Pressure		
				40,000-psi. Fiber Stress	50,000-psi. Fiber Stress	40,000-psi. Fiber Stress	50,000-psi. Fiber Stress	Butt Weld—Plain or Threaded Ends	Lap Weld—Grade A Seamless or Electric-Welded	
									Plain Ends	Threaded Ends
in.	*in.*	*in.*	*lb.*	*psi.*	*psi.*	*psi.*	*psi.*	*psi.*	*psi.*	*psi.*
⅛	0.405	0.068	0.24	3360		13430		700	700	700
¼	0.540	0.088	0.42	3260		13040		700	700	700
⅜	0.675	0.091	0.57	2700		10780		700	700	700
½	0.840	0.109	0.85	2600		10380		700	700	700
¾	1.050	0.113	1.13	2150		8610		700	700	700
1	1.315	0.133	1.68	2020		8090		700	700	700
1¼	1.660	0.140	2.27	1690		6750		800	1000	1000
1½	1.900	0.145	2.72	1530		6100		800	1000	1000
2	2.375	0.154	3.65	1300	1620	5190	6480	800	1000	1000
2½	2.875	0.203	5.79	1410	1770	5650	7060	800	1000	1000

NOTE: Sizes above shall be considered as service pipe.

3	3.500	0.125	4.51	710	890	2860	3570	800	1300	
		0.156	5.58	890	1110	3560	4460	800	1600	
		0.188	6.63	1070	1340	4300	5370	800	1900	
		0.216	7.58	1230	1540	4940	6170	800	2200	1000
		0.250	8.68	1430	1790	5720	7140	800	2500	
		0.281	9.67	1610	2010	6420	8030	800	2500	
		0.300	10.25	1710	2140	6860	8570	800	2500	
3½	4.000	0.125	5.17		780		3120		1100	
		0.156	6.41		980		3900		1400	
		0.188	7.63		1180		4700		1700	
		0.226	9.11		1410		5650		2000	1200
		0.250	10.01		1560		6250		2200	
		0.281	11.17		1760		7020		2500	
		0.318	12.51		1990		7950		2500	
4	4.500	0.125	5.84		690		2780		1000	
		0.156	7.25		870		3470		1200	
		0.188	8.64		1040		4180		1500	
		0.219	10.00		1220		4870		1700	
		0.237	10.79		1320		5270		1900	1200
		0.250	11.35		1390		5560		2000	
		0.281	12.67		1560		6240		2200	
		0.312	13.98		1730		6930		2500	
		0.337	14.98		1870		7490		2500	

Sec. A4–3.1—Mill Pipe (Continued)

Nominal Size	Outside Diam.	Wall Thickness (Decimal)	Weight per Linear Foot	Working Pressure (Safety Factor of 4.0)		Approximate Ultimate Bursting Pressure		Test Pressure		
				40,000-psi. Fiber Stress	50,000-psi. Fiber Stress	40,000-psi. Fiber Stress	50,000-psi. Fiber Stress	Butt Weld—Plain or Threaded Ends	Lap Weld—Grade A Seamless or Electric-Welded	
									Plain Ends	Threaded Ends
in.	*in.*	*in.*	*lb.*	*psi.*	*psi.*	*psi.*	*psi.*	*psi.*	*psi.*	*psi.*
5	5.563	0.156	9.02		700		2800		1000	
		0.188	10.76		850		3380		1200	
		0.219	12.49		980		3940		1400	
		0.258	14.62		1160		4640		1700	1200
		0.281	15.87		1260		5050		1800	
		0.312	17.52		1400		5610		2000	
		0.344	19.16		1550		6180		2200	
		0.375	20.78		1690		6740		2400	
6	6.625	0.188	12.89		710		2840		1000	
		0.219	14.97		830		3300		1200	
		0.250	17.02		940		3780		1400	
		0.280	18.97		1060		4220		1500	1200
		0.312	21.07		1180		4710		1700	
		0.344	23.06		1300		5190		1900	
		0.375	25.03		1420		5660		2000	
		0.432	28.57		1630		6520		2300	
8	8.625	0.188	16.90		550		2180		800	
		0.219	19.64		640		2540		900	
		0.250	22.36		730		2900		1000	
		0.277	24.70		800		3210		1200	1200
		0.312	27.74		900		3620		1300	
		0.322	28.55		930		3730		1300	1200
		0.344	30.40		1000		3990		1400	
		0.375	33.04		1090		4350		1600	
		0.438	38.26		1270		5080		1800	
		0.500	43.39		1450		5800		2100	
10	10.750	0.188	21.15		440		1750		650	
		0.219	24.60		510		2040		750	
		0.250	28.04		580		2330		850	
		0.279	31.20		650		2600		1000	1000
		0.307	34.24		710		2860		1000	1000
		0.344	38.20		800		3200		1100	
		0.365	40.48		850		3400		1200	1000
		0.438	48.19		1020		4070		1500	
		0.500	54.74		1160		4650		1700	
12	12.750	0.188	25.15		370		1480		500	
		0.219	29.28		430		1720		600	
		0.250	33.38		490		1960		700	
		0.281	37.45		550		2200		800	
		0.312	41.51		610		2450		900	
		0.330	43.77		650		2590		1000	1000
		0.344	45.55		670		2700		1000	
		0.375	49.56		740		2940		1100	1000
		0.438	57.53		860		3440		1200	
		0.500	65.42		980		3920		1400	

Sec. A4–3.1—Mill Pipe (Continued)

Nominal Size	Outside Diam.	Wall Thickness (Decimal)	Weight per Linear Foot	Working Pressure (Safety Factor of 4.0)		Approximate Ultimate Bursting Pressure		Test Pressure		
				40,000-psi. Fiber Stress	50,000-psi. Fiber Stress	40,000-psi. Fiber Stress	50,000-psi. Fiber Stress	Butt Weld—Plain or Threaded Ends	Lap Weld—Grade A Seamless or Electric-Welded	
									Plain Ends	Threaded Ends
in.	*in.*	*in.*	*lb.*	*psi.*	*psi.*	*psi.*	*psi.*	*psi.*	*psi.*	*psi.*
14	14.000	0.188	27.65		340		1340		450	
		0.219	32.19		390		1560		550	
		0.250	36.71		450		1780		650	
		0.281	41.21		500		2010		700	
		0.312	45.68		560		2230		800	
		0.344	50.14		610		2460		900	
		0.375	54.57		670		2680		950	950
		0.438	63.37		780		3130		1100	
		0.500	72.09		890		3570		1300	
16	16.000	0.188	31.66		290		1180		400	
		0.219	36.86		340		1370		500	
		0.250	42.05		390		1560		550	
		0.281	47.22		440		1760		650	
		0.312	52.36		490		1950		700	
		0.344	57.48		540		2150		750	
		0.375	62.58		590		2340		850	850
		0.438	72.72		680		2740		1000	
		0.500	82.77		780		3120		1100	
18	18.000	0.188	35.67		260		1040		350	
		0.219	41.54		300		1220		400	
		0.250	47.39		350		1390		500	
		0.281	53.22		390		1560		550	
		0.312	59.03		430		1730		600	
		0.344	64.82		480		1910		700	
		0.375	70.59		520		2080		750	
		0.438	82.06		600		2430		900	
		0.500	93.45		690		2780		1000	
20	20.000	0.188	39.67		240		940		350	
		0.219	46.21		270		1100		400	
		0.250	52.73		310		1250		450	
		0.281	59.23		350		1400		500	
		0.312	65.71		390		1560		550	
		0.344	72.16		430		1720		600	
		0.375	78.60		470		1880		700	
		0.438	91.41		550		2190		800	
		0.500	104.13		630		2500		900	
22	22.000	0.188	43.68		210		860		300	
		0.219	50.88		250		1000		350	
		0.250	58.07		280		1140		400	
		0.312	72.38		350		1420		500	
		0.344	79.51		390		1560		550	
		0.375	86.61		430		1700		600	
		0.438	100.75		500		1990		700	
		0.500	114.81		570		2270		800	

Sec. A4–3.1—Mill Pipe (Concluded)

Nominal Size	Outside Diam.	Wall Thickness (Decimal)	Weight per Linear Foot	Working Pressure (Safety Factor of 4.0)		Approximate Ultimate Bursting Pressure		Test Pressure		
				40,000-psi. Fiber Stress	50,000-psi. Fiber Stress	40,000-psi. Fiber Stress	50,000-psi. Fiber Stress	Butt Weld—Plain or Threaded Ends	Lap Weld—Grade A Seamless or Electric-Welded	
									Plain Ends	Threaded Ends
in.	*in.*	*in.*	*lb.*	*psi.*	*psi.*	*psi.*	*psi.*	*psi.*	*psi.*	*psi.*
24	24.000	0.188	47.68		200		780		300	
		0.219	55.56		230		910		300	
		0.250	63.41		260		1040		350	
		0.312	79.06		330		1300		450	
		0.344	86.85		360		1430		500	
		0.375	94.62		390		1560		550	
		0.438	110.10		460		1820		650	
		0.500	125.49		520		2080		750	
26	26.000	0.188	51.69		180		720		250	
		0.219	60.23		210		840		300	
		0.250	68.75		240		960		350	
		0.281	77.25		270		1080		400	
		0.312	85.73		300		1200		400	
		0.375	102.62		360		1440		500	
		0.438	119.44		420		1680		600	
		0.500	136.17		480		1920		700	
28	28.000	0.188	55.69		170		670		250	
		0.219	64.90		200		780		250	
		0.250	74.09		220		890		300	
		0.281	83.26		250		1000		350	
		0.312	92.40		280		1110		400	
		0.375	110.63		340		1340		450	
		0.438	128.78		390		1560		550	
		0.500	146.85		450		1780		650	

Sec. A4–3.2—Fabricated Pipe *

Outside Diam.†	Wall Thickness†		Weight per Linear Foot	Working Pressure (Safety Factor of 4.0) 50,000-psi. Fiber Stress	Approx. Ultimate Bursting Pressure 50,000-psi. Fiber Stress	Test Pressure
	Mfr.'s Std. Gage No.	Decimal				
in.		*in.*	*lb.*	*psi.*	*psi.*	*psi.*
4	12	0.105	4.46	660	2620	1000
	10	0.135	5.69	840	3380	1200
6	12	0.105	6.75	440	1750	600
	10	0.135	8.64	560	2250	800
		0.188	11.63	780	3130	1100
		0.219	13.50	910	3650	1300
		0.250	15.35	1040	4170	1500
8	12	0.105	9.04	330	1310	450
	10	0.135	11.58	420	1690	600
	7	0.179	15.36	560	2240	800
		0.188	15.64	590	2350	850
	3	0.239	20.32	750	2990	1100
10	10	0.135	14.53	340	1350	450
	7	0.179	19.28	450	1790	650
		0.188	19.64	470	1880	700
	3	0.239	25.55	600	2390	850
12	10	0.135	17.47	280	1120	400
	7	0.179	23.21	370	1490	550
		0.188	23.65	390	1570	550
	3	0.239	30.79	500	1990	700
14	10	0.135	20.42	240	960	350
	7	0.179	27.14	320	1280	450
		0.188	27.65	340	1340	450
	3	0.239	36.03	430	1710	600
16	10	0.135	23.36	210	840	300
	7	0.179	31.06	280	1120	400
		0.188	31.66	290	1180	400
	3	0.239	41.26	370	1500	550
		0.250	42.05	390	1560	550
		0.312	52.36	490	1950	700
18	10	0.135	26.31	190	750	250
	7	0.179	34.99	250	990	350
		0.188	35.67	260	1040	350
	3	0.239	46.50	330	1330	450
		0.250	47.39	350	1390	500
		0.312	59.03	430	1730	600

* Pipe thicknesses shown above the single hairline cross-rule (shown thus ————————) in each pipe size group are those used in the Pacific Coast and Rocky Mountain areas.

† Other diameters and other wall thicknesses can be furnished if required.

Sec. A4–3.2—Fabricated Pipe* (Continued)

Outside Diam.†	Wall Thickness†		Weight per Linear Foot	Working Pressure (Safety Factor of 4.0) 50,000-psi. Fiber Stress	Approx. Ultimate Bursting Pressure 50,000-psi. Fiber Stress	Test Pressure
	Mfr.'s Std. Gage No.	Decimal				
in.		*in.*	*lb.*	*psi.*	*psi.*	*psi.*
20	10	0.135	29.25	170	680	250
	7	0.179	38.92	220	900	300
		0.188	39.67	240	940	350
	3	0.239	51.73	300	1200	400
		0.250	52.73	310	1250	450
		0.312	65.71	390	1560	550
		0.375	78.60	470	1880	700
22	7	0.179	42.84	200	820	300
		0.188	43.68	210	860	300
	3	0.239	56.97	270	1090	400
		0.250	58.07	280	1140	400
		0.312	72.38	350	1420	500
		0.375	86.61	430	1700	600
24	7	0.179	46.77	190	740	250
		0.188	47.68	200	780	300
	3	0.239	62.21	250	1000	350
		0.250	63.41	260	1040	350
		0.312	79.06	330	1300	450
		0.375	94.62	390	1560	550
		0.438	110.10	460	1820	650
		0.500	125.49	520	2080	750
26	7	0.179	50.70	170	690	250
		0.188	51.69	180	720	250
	3	0.239	67.44	230	920	300
		0.250	68.75	240	960	350
		0.312	85.73	300	1200	400
		0.375	102.62	360	1440	500
		0.438	119.44	420	1680	600
		0.500	136.17	480	1920	700
28	7	0.179	54.62	160	640	250
		0.188	55.69	170	670	250
	3	0.239	72.68	210	860	300
		0.250	74.09	220	890	300
		0.312	92.40	280	1110	400
		0.375	110.63	340	1340	450
		0.438	128.78	390	1560	550
		0.500	146.85	450	1780	650

* Pipe thickness esshown above the single hairline cross-rule (shown thus ————————) in each pipe size group are those used in the Pacific Coast and Rocky Mountain areas-

† Other diameters and other wall thicknesses can be furnished if required.

American Water Works Association

TENTATIVE EMERGENCY SPECIFICATIONS *for* REINFORCED CONCRETE PRESSURE PIPE

The American Water Works Association has approved and promulgates these "Tentative Emergency Specifications for Reinforced Concrete Pressure Pipe." They are based upon the best known experience and are intended for use under normal conditions. They are not designed for unqualified use under all conditions and the advisability of use of the material herein specified for any installation must be subjected to review by the engineer responsible for the installation in the particular locality concerned.

These specifications cover pipe manufacture only. Specifications for laying the pipe should include provisions that the purchaser may stipulate that the manufacturer of concrete pipe be required to furnish a competent superintendent on the job when the pipe is laid and that such superintendent shall ascertain that all joints are made in accordance with the manufacturer's recommended practice. Pipe-laying specifications should also provide that the purchaser may stipulate that pipe laid under the manufacturer's supervision shall, after hydrostatic test, exhibit no greater rate of breakage than that stipulated in Sec. 15 of the "A.W.W.A. Specifications for Laying Cast-Iron Pipe—7D–1938" for pipe of equal diameter.

The three types of pipe covered in these specifications are not alternates. The bidder should choose the type which is applicable to the individual installations.

These tentative emergency specifications were not developed under ordinary committee routine, but were prepared by Ernest W. Whitlock, as Engineer-Editor, under the auspices of Committee 7B on Reinforced Concrete Pipe, Malcolm Pirnie, Advisor. They were reviewed by the Committee on Water Works Practice and the Board of Directors and were approved for publication as of January 19, 1943.

A critical review of and comments upon the text by any interested water works man will be appreciated. Correspondence related to the specifications should be addressed to the American Water Works Association, 500 Fifth Avenue, New York, N.Y.

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TENTATIVE EMERGENCY SPECIFICATIONS FOR REINFORCED CONCRETE PRESSURE PIPE

Section 1—General

Sec. 1.1—Scope

The following specifications cover three general types of concrete pressure pipe (Table 1) which are described and specified separately as to type, designation, size range, minimum design head, maximum operating head and materials and methods used in their construction. These specifications cover pipe for use under field conditions wherein the cover over the pipe is 5 ft. or less and the pipe is to be laid in a flat-bottom trench with backfilling tamped as described in ASA A21.1–1939, "Manual for the Computation of Strength and Thickness of Cast-Iron Pipe." If conditions of laying are different from those stated above, investigation of need for additional reinforcing or a concrete cradle should be made.

TABLE 1

Type	Designation	Size Range	Min. Design Head	Max. Operating Head
		in.	*ft.*	*ft.*
A	Steel Cylinder Reinforced Concrete Pressure Pipe	20–150	100	600
B	Non-Cylinder Reinforced Concrete Pressure Pipe	20–150	50	100
C	Centrifugal Reinforced Concrete Pressure Pipe	6–84	50	150

The three types of pipe are not alternates. The bidder should choose the type of pipe, from those covered in these specifications, which is applicable to the individual installation.

Section 2—Clauses Applying to All Types

Sec. 2.1—General Description

2.1.1. All pipes shall be made by a manufacturer who, for a period of at least five years, has produced concrete pressure pipe of the type, size and quality herein specified and whose product has been successfully used on projects of large magnitude in the United States.

2.1.2. If agreeable to the purchaser, a manufacturer who has not had the five-year experience above noted may make acceptable bids, if such manufacturer has satisfactory financial resources, competent engineering personnel and if he furnishes the purchaser adequate and satisfactory bond to guarantee production of properly made pipe.

EDITORIAL NOTE: Next to the last paragraph now in the box on the title page was placed in that position as the result of the majority vote of the A.W.W.A. Board of Directors and the Committee on Water Works Practice. Three members of the Board and three members of the Committee voted to retain it in section two of the body of the document. This difference of opinion can be adjusted when these tentative emergency specifications are considered for standard status.

2.1.3. The internal diameter of the pipe shall not be less than the nominal diameters specified or shown. Joints for each kind of pressure pipe shall be the particular type specified for that type of pipe. All pipes shall be round and true and shall have smooth and dense finished surfaces.

Sec. 2.2—Place of Manufacture and Storage

Where feasible, particularly on projects which require a considerable quantity of large pipe, the pipe shall be manufactured and stored at a plant constructed by the manufacturer, close enough to the site of the work for economical delivery to the trench by truck. The manufacturer shall provide a watchman at the yard, who shall keep out all unauthorized persons and shall maintain the plant in a neat and serviceable condition.

Sec. 2.3—Data to Be Submitted by the Manufacturer

Drawings and schedules showing full details of reinforcement, concrete and joints for the straight pipe, specials and connections, as well as assembly, shall be furnished by the manufacturer. All drawings and schedules shall be submitted for approval in quadruplicate and one copy shall be returned to the manufacturer after approval. No pipe shall be manufactured until drawings have been approved. The manufacturer shall be responsible for the accurate detail, fabrication and fitting of the pipe. Where the conditions of the job permit, drawings and schedules shall include a location profile, referred to the stationing on the contract drawings, showing each section of the line where the design head is different, the design head and station of beginning and end of the section, and lists showing size of pipe, serial numbers, design head, thickness of pipe and area of steel in the reinforcing cage or steel cylinder, or both, per linear foot of pipe.

Sec. 2.4—Marking

Each special and straight pipe must have plainly marked on it the head for which it is designed, the date of manufacture and marks of identification sufficient to show its proper location in the line by reference to the layout drawings and schedules which are required to be furnished by the manufacturer as stated in Sec. 2.3.

Sec. 2.5—Cement

All cement shall meet the requirements of the "Standard Specifications and Tests for Portland Cement," A.S.T.M. Serial Designations C150–41 and C77–40 and all subsequent amendments thereto, or, for the duration of the war emergency, shall be the available product which most nearly meets these requirements. It shall be manufactured at an approved established American plant of recognized capacity and quality of output. A barrel shall be considered as 4 cu.ft. or 376 lb. All cement shall be stored in a dry, well ventilated place and shall be properly protected from weather. Cement that has become lumpy shall not be used. Acceptance or mill tests of cement shall not deprive the purchaser of the right to reject it on the basis of subsequent tests.

Sec. 2.6—Fine Aggregate

Fine aggregate shall consist of clean, hard, durable, insoluble, uncoated particles, free from lumps of clay, soft or flaky materials, loam or

organic material. In no case shall fine aggregate containing lumps of frozen materials be used. When tested by means of laboratory screens and sieves, fine aggregate shall conform to the following requirements:

Screen and Sieve Tests	*Min.*	*Max.*
Passing ⅜-in. sieve	100%	—
Passing No. 4 sieve	95%	100%
Passing No. 50 sieve	10%	30%
Passing No. 100 sieve	2%	5%

The fine aggregate shall contain not more than 3 per cent of clay and inorganic silt by actual dry weight, and must produce a portland cement mortar which will have, at the age of 7 and 28 days, a tensile or compressive strength of not less than 100 per cent of that developed by a mortar prepared in the same manner, of the same proportions and consistency, made of the same cement and standard Ottawa sand. The fine aggregate must be washed aggregate and, when subjected to the color test for organic impurities, it shall produce a color in the sodium hydroxide solution not darker than Fig. 1, using A.S.T.M. Serial Designation C40–33.

Sec. 2.7—Coarse Aggregate

Coarse aggregate for the concrete shall consist of fragments of hard durable insoluble stone or clean sound insoluble gravel. It shall not contain dust, loam, clay, alkali, perishable matter or improper substances and shall be free from injurious amounts of soft, friable, thin, flaky, elongated or laminated particles. It shall be washed or screened, or both if necessary, to remove such substances. Coarse aggregate shall be so stored and handled as to remain clean and well graded at all times and shall be kept separate from other aggregates until placed in the mixer. It shall be well graded from fine to coarse and shall have a maximum size of ½ in. for pipe 20 in. and less in diameter, and ¾ in. for pipe more than 20 in. in diameter or larger material with the approval of the engineer.

Sec. 2.8—Concrete

The concrete used in the manufacture of types A and B pipe shall consist of approximately 1 part of cement, 1¾ parts of fine aggregate and 2½ parts of coarse aggregate, measured by volume. For the purpose of securing greater density, the proportions shall be varied as required or approved, but in no case shall the cement content be less than 1 part of cement to 4¼ parts of fine aggregate plus coarse aggregate, measured separately by volume. The maximum ratio of water to cement shall be 5½ U.S. gal. to 1 bag of cement. At least two test cylinders shall be taken of each day's pour, cured under the same conditions as the pipe. A 28-day compressive strength test shall be made by the manufacturer. The concrete shall have a minimum 28-day compressive strength of 3500 psi.

Sec. 2.9—Steel Reinforcing Cages

Pipe sections shall be reinforced with one or more cages of welded steel hoops, welded steel fabric or helically wound steel rods properly spaced and supported by longitudinal reinforcing or spacers. The cage reinforcement steel shall conform to the "Standard Specifications for Billet-Steel Concrete Reinforcement Bars, Structural Grade," A.S.T.M. Serial Designation A15–39 and all subsequent amendments thereto.

Hoops, where used, shall be flash butt welded and shall be uniform in

diameter. Each hoop weld shall be tested to a stress of 30,000 psi. before being assembled in the cage.

Sec. 2.10—Curing of Pipe

The manufacturer shall provide adequate steam plant, necessary piping and facilities for curing the pipe sections. After the pipe has been cast, it shall be cured sufficiently by approved means so that the removal of the forms will not damage the concrete. Steam may be used for curing and shall be used if the temperature is below 50°F. The atmosphere in the steam room shall have a temperature not exceeding 120°F. and such humidity that the exposed surfaces of the pipe shall be moist at all times. After the removal of the forms, the curing shall be carried on by keeping the pipe moist during the daylight hours for at least ten days or by an approved combination of steaming and sprinkling. If the sprinkling method is used, the pipe, including the ends, shall be covered with burlap for the first three days. The burlap covering may be omitted provided that the pipe is kept constantly and thoroughly wet with fog sprays during the daylight hours. No pipe shall be removed from the yard until the expiration of the curing period.

Section 3—Type A—Steel Cylinder Reinforced Concrete Pressure Pipes

Sec. 3.1—General Description

Steel cylinder reinforced concrete pressure pipe shall consist of a continuous welded steel cylinder with steel joint rings welded to its ends, lined with not less than 1 in. of concrete and covered on the outside with concrete, reinforced by a cage of spirally wound steel rods, welded fabric or welded circumferential hoops which are securely supported by, or attached to, longitudinals of such size and spacing as to support the cage properly. Straight pipe shall, in general, be 12 or 16 ft. in length and angle pipes, reducers and other fittings may be made in shorter lengths. The rubber gasket type of joint shall be used for pipe smaller than 36 in. and either the rubber gasket or lead gasket type shall be used for 36-in. and larger pipe.

Sec. 3.2—Minimum Wall Thickness

The wall thickness for each size of pipe shall be no less than the following:

Inside Diam., in.	*Min. Wall Thickness, in.*	*Inside Diam., in.*	*Min. Wall Thickness, in.*
20	3⅛	48	4½
24	3½	51	5
27	3½	54	5
30	3½	60	5½
34	3½	66	6
36	3½	72	6½
39	4	78	7
42	4	84	7½
46	4½		

For diameters greater than 84 in., the wall thickness shall be determined to meet the conditions of each case.

Sec. 3.3—Design and Fabrication of Steel

The minimum thickness of cylinder shall be No. 16 gage, U.S. Standard. All pipes shall be reinforced with an arc-welded steel cylinder attached to the joint rings by arc welding and an outside cage, or cages, of steel bars with spacing maintained by longitudinal bars or by No. 8 gage, U.S. Standard, wire on 9-in. centers or equivalent area. The total area of cir-

cumferential steel in the pipe shall be such that the steel will not be stressed in excess of 12,500 psi. when the pipe is subjected to the internal pressure fixed for the design. The cross-section of the steel cage or cages outside the cylinder shall not be less than 40 per cent of the total area of the circumferential steel, including both the cylinder and cages. Steel sheets for cylinders shall conform to the requirements of A.S.T.M. Serial Designation for "Low Tensile Strength Carbon-Steel Plates for Welding, Grade B," as last revised, except that the yield-point shall be 30,000 psi. Before the cage is placed about the cylinder, the cylinder shall be subjected to a hydrostatic test by closing the ends at the joint rings, filling with water in contact at all points with the welds and raising the water pressure to stress the circumferential steel to 20,000 psi. While under pressure test, all welds shall be thoroughly inspected. All leaks shall be repaired by removing the defective part of the weld and by re-welding; and the cylinder shall be re-tested. The finished cylinder with joint rings attached shall be water-tight under the required test pressure. Arc welding shall be done by an approved process and test welds shall be furnished from the work as required.

Sec. 3.4—Forms

The forms shall be of steel made with butt joints throughout, and with interior surfaces smooth and true. The forms shall be so constructed that the inner and outer forms, joint rings and reinforcement shall be held in circular and concentric positions; and they shall be so designed that the inside form can be collapsed and the outside form expanded to allow both readily to be removed from the pipe without injury to the freshly set concrete. Forms shall be sufficiently tight to prevent leakage of mortar and shall be stiff enough and so braced as to withstand all operations incident to pouring and setting of the concrete without deformation of any kind. Forms shall be cleaned and oiled before each use.

Sec. 3.5—Casting

The pipes shall be cast on end. The concrete shall be deposited in the forms with the aid of vibration and the forms shall be continuously vibrated during the placing of each batch of concrete. The transporting and placing of concrete into the molds shall be done by approved methods such that no separation of materials or distortion of forms will occur.

Sec. 3.6—Specials and Fittings

The manufacturer shall furnish all fittings, bends and special pieces for closures, branches, manholes, air-valve and blow-off connections and connections to main-line valves, as shown in schedules or on contract drawings. Unless otherwise permitted or required, openings for branches, manholes and other connections and flanges, or spigots for connections to main-line valves and connections to existing pipes shall be built into the walls of the pipe. This shall be done by welding fittings of cast steel or structural steel of suitable design into the cylinder of the main pipe, welding or otherwise securely attaching them to the other reinforcement of the pipe, before the pipe is molded, and surrounding them with sufficient reinforced concrete to give the required strength.

Sec. 3.7—Curves and Bends

Curves of short radius and bends shall be formed by bends of the same type of construction as straight pipe except that the cylinder sheets shall be cut and welded to the necessary shape to produce the proper-shaped curve or bend. Curves of long radius may be formed by beveling one end of the pipe, but the total angular deflection shall not exceed five degrees at any joint. Slight deflections may be made with straight pipe.

Sec. 3.8—Joint Rings

The joint rings shall be in accordance with the detail submitted by the manufacturer for either the rubber gasket or lead gasket joint, as required. They shall be made of steel conforming to the requirements of A.S.T.M. Serial Designation A78–33, "Low Tensile Strength Carbon-Steel Plates of Structural Quality for Welding, Grade A," and all subsequent revisions thereof. The minimum thickness of the completed bell and spigot rings shall be $\frac{3}{16}$ in. Each joint ring shall be formed of one or more pieces butt welded together by a resistance welder or by a hand electric arc weld. They shall be stretched by an expanding press accurately to the required diameter and finished in an approved manner. The faces of the rings which will be exposed after the pipe is cast shall be covered with an approved paint to protect them from corrosion.

Sec. 3.9—Rubber Gasket Joint

The ring forming the bell end of the pipe shall be covered on its exterior surface with reinforced concrete and the ring forming the spigot end shall be lined on its inner surface with concrete. The joint ring shall be so shaped as to enclose the gasket on all sides. The joints shall be self-centering and the rings forming the joints shall be of such shape and dimensions that the pipes will center themselves without the aid of the rubber gasket.

The joint shall be so designed and the gasket so placed that the gasket will not be required to support the weight of the pipe, but will keep the joint tight under all conditions of service, including expansion, contraction and normal earth settlement.

The gasket sealing the joint shall be made of rubber of special composition having a texture to assure a watertight and permanent seal and shall be the product of a manufacturer having at least five years of experience * in the manufacture of rubber gaskets for pipe joints. The gasket shall be a continuous ring, of approved cross-section and of such size as completely to fill the groove on the spigot joint ring when the pipes are laid. The rubber gasket shall be the sole element depended upon to make the joint watertight. Cement mortar or plastic materials used to complete the joint-making shall not be depended upon for watertightness.

Sec. 3.10—Lead Gasket Joint

The bell end of the pipe shall be formed by the projection of the steel ring, covered on its exterior surface by reinforced concrete. The spigot end shall be formed by a ring having

* In lieu of "five years of experience," the purchaser may accept the product of a manufacturer having less experience, if the purchaser is satisfied that such manufacturer has satisfactory financial resources and competent engineering personnel and if the manufacturer furnishes the purchaser adequate and satisfactory bond to guarantee production of properly made gaskets.

a ridge and covered on its inner surface with reinforced concrete. The joint shall be so designed that, when the two pipes are placed together, there will be a wedge-shaped recess between the two joint rings, into which recess there shall be placed and calked a continuous lead-covered fiber-filled gasket of approved design and manufacture.

The joint shall be so designed that the lead gasket can be calked from the inside of the pipe after the pipe is laid and backfilled and after all settlement has taken place.

Section 4—Type B—Non-Cylinder Reinforced Concrete Pressure Pipe

Sec. 4.1—General Description

Reinforced concrete pressure pipe without cylinder shall consist of one or more reinforcing cages enclosed in concrete poured in metal forms. The pipe shall be poured in a vertical position in 12- or 16-ft. lengths. Joints shall be constructed with self-centering steel rings. The rubber gasket type of joint shall be used for pipe smaller than 36 in. in diameter and either the rubber or lead gasket type of joint shall be used for 36-in. and larger pipe.

Sec. 4.2—Minimum Wall Thickness

The inside diameter and minimum wall thickness are listed below:

Inside Diam.,	*Min. Wall Thickness,*	*Inside Diam.,*	*Min. Wall Thickness,*
in.	*in.*	*in.*	*in.*
20	3½	48	5
24	3½	51	5
27	3½	54	5½
30	3½	60	6
34	3½	66	6½
36	4	72	7
39	4	78	7½
42	4½	84	8
46	4½		

For diameters greater than 84 in., the wall thickness shall be determined to meet the conditions of each case.

Sec. 4.3—Forms

The pipes shall be cast on end in steel forms made with butt joints throughout and with the interior surface perfectly smooth and true. They shall be made in such a way as to hold the circumferential steel cages and the inner and outer forms rigidly in concentric position. The forms shall be so designed that the inside form can be collapsed and the outside form expanded to allow both to be removed readily from the pipe without injury to the freshly set concrete. Forms shall be sufficiently tight to prevent leakage of mortar, and shall be stiff enough and so braced as to withstand all operations incident to the pouring and setting of the concrete without deformation of any kind. All forms shall be thoroughly cleaned and oiled before each use.

Sec. 4.4—Placing of Concrete

The concrete shall be placed in each form continuously until it is filled. Approved mechanical vibrators shall be used continuously until all of the concrete in each form is placed, in order to insure uniform and dense concrete.

Sec. 4.5—Steel Reinforcing Cages

The total cross-sectional area of circumferential steel in the pipe wall shall not be less than an amount sufficient to resist the internal operating pressure for which it is designed at a stress of 10,000 psi. Longitudinal bars or rods shall extend from end to end of the cage and those of the inner cage shall

be welded to the joint rings. They shall be equivalent to $\frac{1}{2}$-in. bars spaced not more than 24 in. apart in each cage. All steel reinforcement shall have a minimum concrete cover of $\frac{3}{4}$ in. and all pipes of this type shall be designed for a minimum head of 50 ft. Approved means shall be used to keep reinforcing in proper position as the pipe is poured.

Sec. 4.6—Rubber Gasket Joint

Joint rings shall meet the requirements of Sec. 3.8. They shall be securely welded to the steel reinforcing. The ring forming the bell end shall be covered on its exterior surface with reinforced concrete and the ring forming the spigot end shall be lined with concrete. The joint rings shall be so shaped as to enclose the gasket on all sides. The joints shall be self-centering and the rings forming the joints shall be of such shape and dimensions that the pipes will center themselves without the aid of the rubber gasket.

The joint shall be so designed and the gasket so placed that the gasket will not be required to support the weight of the pipe, but will keep the joint tight under all conditions of service, including expansion, contraction and normal earth settlement.

The gasket sealing the joint shall be made of rubber of special composition having a texture to assure a watertight and permanent seal and shall be the product of a manufacturer having at least five years of experience * in the manufacture of rubber gaskets for pipe joints. The gasket shall be a continuous ring of approved cross-section and of such size as completely to fill the groove on the spigot joint ring when the pipes are laid. The rubber gasket shall be the sole element depended upon to make the joint watertight. Cement mortar or plastic materials used to complete the joint-making shall not be depended upon for watertightness.

Sec. 4.7—Lead Gasket Joint

Joint rings shall meet the requirements of Sec. 3.8. The bell end of the pipe shall be formed by the projection of the steel ring, covered on its exterior surface by reinforced concrete. The spigot end shall be formed by a ring having a ridge and covered on its inner surface with reinforced concrete. The joint shall be so designed that, when the two pipes are placed together, there will be a wedge-shaped recess between the two joint rings, into which recess there shall be placed and calked a continuous lead-covered fiber-filled gasket of approved design and manufacture.

The joint shall be so designed that the lead gasket can be calked from the inside of the pipe after the pipe is laid and backfilled and after all settlement has taken place.

* *See* footnote on page 506.

Section 5—Type C—Centrifugal Reinforced Concrete Pressure Pipe

Sec. 5.1—General Description

Centrifugal reinforced concrete pressure pipe shall be manufactured from portland cement concrete in which special steel reinforcement cages have been imbedded. Pipe sections over 12 in. in diameter shall be not less than 8 ft. long and those 12 in. or less in diameter shall be not less than 6 ft. long. The pipe shall be cast in steel molds with cast or fabricated metal end rings, so constructed as to mold the pipe accurately and to true dimension.

Sec. 5.2—Minimum Wall Thickness

Pipe shall have inside dimensions and minimum wall thickness as follows:

Inside Diam., *in.*	*Min. Wall Thickness,* *in.*	*Inside Diam.,* *in.*	*Min. Wall Thickness,* *in.*
6–18	1¾	48	4⅛
21	2	51	4¼
24	2¼	54	4½
27	2⅝	57	4⅝
30	2¾	60	5
33	2⅞	63	5¼
36	3⅛	66	5½
39	3¼	69	5¾
42	3⅜	72	6
45	3⅝		

For diameters greater than 72 in., the wall thickness shall be determined to meet the conditions of each case.

Variations of the internal diameter shall not exceed 1.5 per cent. At no point of the circumference of the pipe shall the wall thickness be less than 5 per cent under the minimum average wall thickness specified in the above table. The ends of the pipe shall be at right angles to the longitudinal axis, except where beveled for curves.

Sec. 5.3—Forms

Forms shall consist of cast or fabricated metal end rings and steel plates rolled to true circles to form the outer forms. The forms shall be rigid so that they cannot be distorted while the concrete is being placed in them or while the pipe is being spun. Joints between the plates shall be tight to prevent leakage and the plates shall be locked together in such a manner as to form a true circle with no offset or flat spots at the joint. All forms, when assembled, shall be in balance so that they will permit pipes to be cast with walls of uniform thickness and will revolve without harmful vibration. Runner wheels and end rings shall be free from flat spots which will cause vibration.

Sec. 5.4—Pipe Fabrication Details

Centrifugal concrete pipe shall be spun in a horizontal position on a machine of sufficient rigidity so that there will be no harmful vibration while the pipe is being spun.

After the concrete materials have been mixed, they shall promptly be placed in the forms and spun. Filling of the forms shall be continuous and, if for any reason the work is stopped long enough for the cement to take its initial set, any partly filled forms shall be emptied and the concrete rejected. While the concrete is being placed in the forms, they shall be revolved at such speed as will insure as nearly as possible a uniform distribution of the concrete throughout the wall of the pipe. After all the concrete has been placed in the forms, the speed shall be increased gradually to a speed that will pack the concrete. This speed shall be

maintained for a sufficient length of time to remove the surplus water and secure a dense concrete.

After the concrete is packed, the water, laitance and any float material expelled from the concrete shall be removed from the inner surface of the pipe. This surface shall then be smoothed and shall be subjected to a final spin.

Sec. 5.5—Steel Reinforcing Cages

Cages shall be accurately fabricated to insure uniform spacing in the cage itself and within the pipe wall. Where jointed, circular reinforcement shall lap not less than 30 diameters for bars and 40 diameters for cold-drawn wires, or shall be satisfactorily welded. It shall be sufficient to care for all tensile stresses in the shell of the pipe, caused by the head for which the pipe is designed, without exceeding a stress of 12,500 psi. All steel reinforcement shall have a minimum concrete cover of $\frac{3}{4}$ in. and all pipes of this type shall be designed for a head of at least 50 ft. Sufficient longitudinal reinforcement shall be used to make a stiff cage and to hold the circular reinforcement uniformly spaced. The cage shall be held in proper position in the form by means of longitudinal rods, under tension, passing through the end rings, or by equal approved methods.

Sec. 5.6—Curves and Bends

Sections of pipe with bell or spigot ends beveled, and of approximately the same length as the standard sections of square-ended pipe, may be furnished for curved alignment or bends in the pipeline. For the purpose of reducing the angular deflections at pipe joints, the contractor shall be permitted to install pipe sections in lengths less than 8 ft. on curved alignment, provided that the length of such sections shall in no case be less than 3 ft., measured on the pipe axis. Beveled or angle pipe shall have the same bell and spigot design as that on abutting pipe sections and shall have a maximum deflection of five degrees from a plane perpendicular to the pipe's axis.

Where curves which have a shorter radius than can be accommodated by mitering the pipe are required, or where they are indicated on the drawings, short-radius bends shall be constructed of steel pipe encased in concrete standard steel cylinder pipe bends or cast-in-place bends may be constructed. Such bends shall be equal to abutting pipe sections. Design of such bends and the jointing thereof to the abutting pipe sections shall have the approval of the engineer before construction.

Sec. 5.7—Openings

Castings for openings 6 in. or less in diameter may be spun into the wall of the pipe during fabrication. These castings shall be firmly tied into the wall of the pipe and leakage around the opening may be sufficient cause for rejection of the pipe. Larger openings shall be made by forming a suitable aperture in the wall of the pipe during fabrication and by fitting into and around this aperture a fabricated steel saddle firmly tied to the barrel of the pipe by means of circumferential tie-rods and encased in concrete after the pipe is laid. Designs for all openings and outlets and the seating thereof on the pipeline shall be submitted to the engineer for his approval before fabrication.

Sec. 5.8—Joints

The pipe ends shall be so shaped that the joint will be self-centering;

and, on 20-in. and larger pipe, the ends of the pipe shall be so formed as to leave a recess or joint on the inside of the pipe. Unless otherwise permitted or required, the collar type of joint specified in Sec. 5.9, below, shall be used.

If permitted or required, the manufacturer or contractor shall, for 16-in. and larger pipes, use a rubber gasket type joint, with surfaces of the bell and spigot so shaped as to enclose the gasket on all four sides. The joints shall be of such shapes and dimensions that the pipes will center themselves without the aid of the rubber gasket. The gasket shall not be required to support the weight of the pipe, but shall keep the joint tight under all conditions of service, including expansion, contraction and normal earth settlement. The gasket sealing the joint shall be as specified under Sec. 3.9. Details of the joint and gasket shall be submitted for approval.

Sec. 5.9—Collar Type of Joint

Unless otherwise permitted or required, on centrifugal concrete pressure pipe, a reinforced collar not less than 8 in. in length shall be attached to the bell end of the pipe. The internal diameter of the collar shall be such that the space between the inside of the collar and the outside of the pipe shall be not less than $\frac{5}{8}$ in. nor more than $\frac{3}{4}$ in.

One-half of the length of the collars shall be calked or spun onto the pipe in the yard. If it is calked on, a suitable collar support shall be used to hold the collar concentric with the pipe and to furnish an unyielding surface against which to calk. Neat cement shall be used in calking on the collars and shall be slightly moistened and screened through a $\frac{3}{16}$-in. screen to break up the small lumps. The cement shall be calked in layers not exceeding $1\frac{1}{2}$ in. in thickness with suitable tools and a hammer weighing not less than 3 lb. After the calking is completed, the joint shall be covered and kept moist for at least three days.

Sec. 5.10—Yard Internal Pressure Test

When the pipe has reached an age of at least 28 days, one length out of each day's run may be selected at random by the engineer for testing at the manufacturer's plant. Adequate equipment with which to make such tests shall be provided by the manufacturer and he shall also furnish all labor and material required. Pipe shall be tested for resistance to internal pressure by sealing or bulkheading the ends of the pipe and applying an internal water pressure, for at least 20 min., equal to 120 per cent of the working pressure for which the pipe is designed. Before the test is applied, the pipe shall be filled with water and allowed to stand under a pressure of 10 psi. for at least 3 hr. The pipe must withstand these tests without cracking and with no harmful seepage. Water which merely penetrates the shell of the pipe and adheres to its sides shall not be considered harmful seepage. In the event that a pipe fails to withstand such test, the manufacturer shall have the right to test two other sections of pipe selected at random by the engineer from the same day's run as that from which the original pipe was selected. If these two pipes successfully pass the tests, the remainder of that day's run may be installed. If either fails, the remainder cannot be installed in the line until each pipe has satisfactorily passed this test. Pipes may be tested at seven days or less for 90 per cent, or at fourteen days or less for 108 per cent of said working pressure.

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **34:** 412 (Mar. '42) indicates volume 34, page 412, issue dated March 1942. If the publication is paged by the issue, **34:** 3: 56 (Mar. '42) indicates volume 34, number 3, page 56, issue dated March 1942. Initials following an abstract indicate reproduction, by permission, from periodicals, as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M.—Institute of Metals (British).*

LABORATORY CONTROL—EQUIPMENT AND APPARATUS

Conductivity Test in Industrial Control. NATHAN SCHOLL. The Frontier **5:** 2: 8 ('42). Because of their simplicity, accuracy and speed, elec. cond. measurements useful in such detns. as concn. of solns., purity of water and moisture content of materials, wherever factor to be detd. can be correlated with cond. of material. App. consists essentially of Wheatstone bridge, cathode-ray visual null-point indicator, main control dial, associated amplifier and rectifier tubes and suitable means for sampling material to be tested. Accuracy of instrument within 1%, except for extreme ends of calibration. Typical commercial applications are detn. of concn. of bottle-washing solns., of purity of water in food and beverage industries, of acidity and alky. of solns., detn. of dissolved solids in tap water, testing of boiler feed water and mineral waters and detn. of moisture and sol. salts in soils.—*C.A.*

External Indicators—A Modified Technique in Their Use. ALBERT C. HOLLER. Chem. Analyst **31:** 81 (Nov. '42). In course of electrolytic sepn. using mercury cathode cell, necessary to make certain that deposition complete. Usually done by removing drop of electrolyte and treating it on spot plate with suitable reagent, e.g., spotting of ferrous iron soln. with potassium ferricyanide. Error introduced by removing 5–10 drops for testing large when vol. of electrolyte small (25–50 ml.). Magnitude of induced error depends to considerable extent on whether or not element to be detd. is deposited in mercury cathode. If it remains in electrolyte, induced error in some cases as large as 2–3%; e.g., in detn. of aluminum in aluminum alloys, aluminum remains in soln and Pb, Fe, Zn, etc. deposited in the mercury cathode. After electrolysis complete (spot tests for foreign metals are neg.), electrolyte run off and aluminum detd. as Al_2O_3. Paper describes modified technique using capillary tubes with which to take sample. Amt. of electrolyte used in 10 tests about equal to one drop. Thus, induced error in anal. greatly decreased and becomes almost negligible. *Method:* Glass tubing (soft glass) selected thoroughly cleaned and dried by first cleaning with dichromate-sulfuric acid cleaning soln., rinsing in tap water and then in distd. water and finally removing water with ethyl alcohol and drying. Tubing heated to fusion point, drawn out into capillary tubes of about 0.5 mm. od. and cut into 6″ lengths. To take sample for testing, capillary tube dipped into electrolyte and electrolyte allowed to travel about ½″ up tube before withdrawn. While still holding capillary in vertical position, dip it into test reagent (potassium ferricyanide for ferrous iron) and allow reagent to fill tube addnl. ½″. To observe color reaction between electrolyte and reagent, place tube against white background and enlarge zone of reaction (point at which electrolyte and reagent mixed). This can be done with hand lens of high resolving power, or microscope. Very good results obtained in electrolytic sepn. of copper in brass and bronze. Potassium ferrocyanide used as reagent to test for complete deposition; red color formed in capillary if copper present. One part copper in 2,500,000 can be detected by reagent. Org. reagents, such as acetylacetone for ferric iron and *m*-benzaminosemicarbazide for copper can be used profitably.—*Ed.*

A Simple Laboratory Ozone Generator. RAYMOND RAYMOND. Chem. Analyst **31:** 40 (May '42). Generator which may be constructed at cost not exceeding $16 described. App. consists essentially of 10″ transparent quartz tube, 8 mm. in diam., filled with argon and provided with sealed-in tantalum electrodes, inserted in and insulated from section of 1¼″ brass pipe through which dry O_2 allowed to flow. Quartz tube connected to secondary of transformer furnishing 30 ma. current at 15,000 v., primary being connected to 110-v. line, using small "sign flasher" to switch current on and off automatically, since production of O_3 much greater at moment circuit closed.—*R. E. Thompson.*

Apparatus for Collecting Water Samples From Different Depths for Bacteriological Analysis. CLAUDE E. ZOBELL. J. Marine Res. **4:** 173 (Dec. '41). Merits of different types of sampling app. discussed. Containers made of copper, zinc, tin or other heavy metals not suitable for collection of samples for bact. anal. due to harmful oligodynamic action of heavy metals. Some bacteria killed after 5 min. storage in such containers and water itself may be rendered bacteriostatic by exposure to metals. App. described for collecting samples from any desired depth in ordinary citrate of magnesia or soda-pop bottle. Bottle fitted with 1-hole rubber stopper connected to 5″ length of 5-mm. glass tubing sealed in flame at outer end. Assembled apparatus sterilized in autoclave. Stopper seated while steam still in bottle, thereby providing for evacuated bottle upon cooling. Sterile evacuated bottle clamped to carrier with rubber tubing bent back on itself at angle of 180° in such way that when messenger dropped, end of glass tubing sheared off and rubber tubing straightens out with now open end (water inlet) several inches away from any source of extraneous contamn. App. simple and inexpensive. With multiple units, samples can be collected simultaneously from several different depths. For depths exceeding 200 m., pressure-resistant collapsible bottle recommended. Pear-shaped aspirator bulbs holding about 100 ml. have proved satisfactory for purpose.—*P.H.E.A.*

A Multiple Electromagnetic Water Sampler. L. V. WHITNEY. Trans. Wis. Acad. Sci. **33:** 95 ('41). Description of elec.-operated device, consisting of sampler and microstratification app., with which possible to obtain from body of water, in one operation and at any desired level, 6 samples for bacterial counts.—*C.A.*

A Platinum Scoop for Transferring Sterile Powders. A. PACKCHANIAN. Science **96:** 522 (Dec. 4, '42). Small quants. of sterile powd. or chems. usually transferred to container or medium with loop or large-bore pipette. Thus, some powd. usually spilled or scattered. To overcome difficulty, platinum scoop (shovel) devised. Made by folding piece of platinum sheet into U-shaped shovel attached to inoculating needle holder with platinum wire, Cu wire or lead glass. Of 3 sizes: (a) 24 × 5 × 2 mm., (b) 25 × 5 × 3 mm., (c) 20 × 10 × 3 mm., scoop (a) holds about 0.17 g. of starch powd., (b) 0.23 g., (c) 0.45 g. Scoop successfully used in adding sterile rice starch, starch, charcoal to various media for culturing *Endameba histolytica* and *Trichomonas vaginalis.* Also used in anal. chem. weighings, with advantages over spatulas. Readily sterilized by flame, cools in few seconds, permits large no. of transfers in short time.—*Ralph E. Noble.*

A Tool for Re-Forming Two-Piece Compression Copper Tubing Couplings. J. C. WHITWELL & W. T. MCKEE. Chem. & Eng. News **20:** 1109 (Sept. 10, '42). Several characteristic forms of copper tubing couplings: 2- and 3-piece compression couplings and flared tube couplings. First type (2-piece) cheapest and easiest to install. Square-cut tubing slipped into coupling and top nut tightened in place, seals forming at end of tubing and at brass contact of two nuts. Both other types require more handling: second, in placement of sleeve upon tubing, requiring opening of coupling prior to installation; and third, in placing union nut on tubing, flaring tubing and fastening two parts together. Separate tool used for flaring operation. Main disadvantage to 2-piece coupling inability to re-use top, or compression, nut. In original use, end of compression nut pressed into tubing, gripping it permanently. After initial operation, fitting may be uncoupled and recoupled, but compression nut may not be removed and replaced on another piece of tubing. Re-use on another piece of tubing requires reshaping nut to remove crimp in tapered end. Tool to perform this described. Above difficulty not characteristic of other two types, but in case of sleeve type, sleeve

permanently crimped onto tubing. This single part of fitting not suitable for re-use. In normal times sleeves inexpensive; at present largely unobtainable. Flared tubing coupling may be re-used by cutting off flared end and slipping union nut from tubing. Second reputed objection to double compression fitting unreliability under high pressure. Authors used fittings under 1000 psi. with no difficulty. Tool presented designed and thoroughly tested. Found satisfactory, not only for one, but for successive operations on same fitting. Tool (*see* diagram) consists of block of steel, *A*, and tapered steel rods, *B*, for each size coupling handled. Steel block drilled with several holes, one for each size. Proper sizes indicated in Table 1. Block and rods may be of ordinary low-carbon steel. For best service, rods should be turned from tool steel and subsequently hardened; but low-carbon steel rod will have considerable life. Taper of 12° specified for expanding end of rod arbitrarily chosen and not closely defined. Any moderate taper satisfactory. *Use of Tool:* Compression nut removed by cutting off protruding end of tubing (not over $\frac{1}{8}$" in length). Cut made as near as possible to fitting, but without burring nut with hacksaw teeth. Tubing then filed flush with nut, when latter can be drawn from tubing with comparative ease. If nut fails to draw off easily, few turns with wrench will loosen it. Another method of loosening is clamping nut in vise and twisting tubing by hand. Fundamental to satisfactory re-forming of nut is heat treatment. Crimp in nut has cold-worked brass sufficiently to make it quite brittle. Removal of embrittlement essential. Simply accomplished by heating nut to temp. somewhat below melting point of brass. Operation may be performed in furnace, but hand-torch or gas-air type quite satisfactory for any but very large-scale reclaiming operations. Heat-treated nut placed in proper hole in block, *A*, where supported by hexagon head. Block most satisfactorily held in ordinary machinist's vise. Rod, *B*, of od. corresponding to id. of hole in compression nut selected. Rod

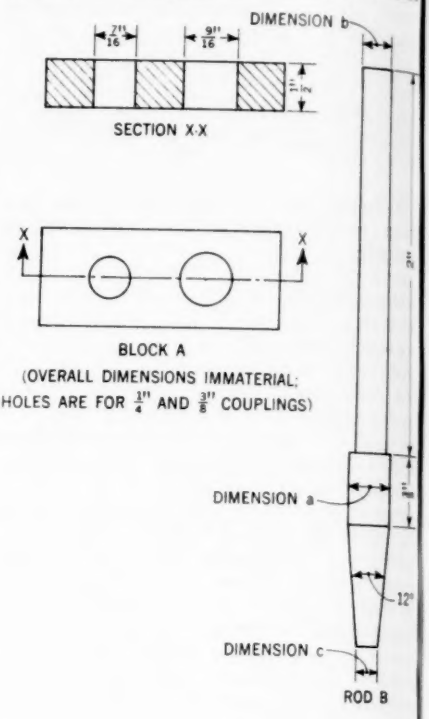


TABLE 1

Copper Tube od.	Nut Threads od.	Diam. of Drill for Hole in Block A	Diam. Tubing Hole in Compression Nut	Diam. Rod B, Dimension *a*	Diam. Rod B, Dimension *b*	Diam. Rod B, Tapered End Dimension *c*	Taper—Total Angle
in.	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*	*deg.*
$\frac{1}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	0.128 to 0.132	0.128	$\frac{3}{32}$	$\frac{1}{16}$	12
$\frac{3}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	0.191 to 0.195	0.191	$\frac{1}{8}$	$\frac{3}{32}$	12
$\frac{1}{4}$	$\frac{7}{16}$	$\frac{7}{16}$	0.253 to 0.257	0.253	$\frac{3}{16}$	$\frac{1}{8}$	12
$\frac{5}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	0.316 to 0.320	0.316	$\frac{1}{4}$	$\frac{3}{16}$	12
$\frac{3}{8}$	$\frac{9}{16}$	$\frac{9}{16}$	0.378 to 0.382	0.378	$\frac{1}{4}$	$\frac{1}{4}$	12
$\frac{7}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	0.441 to 0.446	0.441	$\frac{5}{16}$	$\frac{5}{16}$	12
$\frac{1}{2}$	$\frac{11}{16}$	$\frac{11}{16}$	0.504 to 0.508	0.504	$\frac{3}{8}$	$\frac{3}{8}$	12
$\frac{9}{16}$	$\frac{3}{4}$	$\frac{3}{4}$	0.566 to 0.570	0.566	$\frac{7}{16}$	$\frac{7}{16}$	12
$\frac{5}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	0.628 to 0.632	0.628	$\frac{1}{2}$	$\frac{1}{2}$	12
$\frac{3}{4}$	1	1	0.753 to 0.757	0.753	$\frac{9}{16}$	$\frac{9}{16}$	12

placed in hole in compression nut and gently tapped through with hammer. Reduction in diam. of upper part of rod allows it to fall freely through nut after re-forming operation complete. This essential point in efficient operation. Nut then ready for re-use. No. of repetitions of process should be unlimited. —*Ed.*

Machine-Rolled Stoppers for Culture Tubes. HAROLD W. BACHELOR. (*Published in abstract only.*) J. Bact. **44:** 258 (Aug. '42). Simple lathe constructed for rapid rolling of culture tube stoppers. Latter made of any fibrous material including absorbent and non-absorbent cotton, glass wool, etc., to any desired size with straight or tapered sides to fit random tubes; solid for routine cultures or hollow for pipettes. Machine-rolled stoppers definite in structure and used repeatedly.—*Ralph E. Noble.*

Special Slide Rule for Calcium Carbonate Equilibrium Problems. A. ADLER HIRSCH. Ind. Eng. Chem.—Anal. Ed. **14:** 178 (Feb. '42). Slide rule described enables mech. calcn. of full Langelier and its contractions, deg. of $CaCO_3$ satn., and dissolved CO_2 from pH and alky. values, or vice versa. Also adapted to ordinary multiplication and division. Simplifies calcn. of changes in carbonate or CO_2 values necessary to avoid corrosion or scaling. Slide rule shown in diagram, and use illustrated by examples.—*Selma Gottlieb.*

Electrical Measuring Apparatus for Aluminium Sulfate. G. M. BARTENEV. Vodos. Sanit. Tekh. (U.S.S.R.) **16:** 3: 18 ('41); Chem. Zbl. (Ger.) **2:** 2599 ('41). Usual process of detg. aluminum sulfate in water, which depends on measurements of alky., slow and has error of ±10 to 20%. By means of new electrical process, in which conductivity of water which has been treated with aluminum sulfate compared with conductivity of untreated water, concns. greater than 20 mg./l. aluminum sulfate can be detd. with accuracy of ±3 to 5 mg./l. App. and procedure used described and effect of temp. on accuracy of results discussed.—*W.P.R.*

Slide Rule for Carbonate Equilibria and Alkalinity in Water Supplies. A. A. HIRSCH. Ind. Eng. Chem.—Anal. Ed. **14:** 943 (Dec. '42). Carbonate, bicarbonate and carbon dioxide equilibria relations well adapted for special slide rule designed to provide mech. soln. of equations involved. Constr. of slide rule and method of operation shown.—*Selma Gottlieb.*

Visual Fluid Flowmeters With Straight-Walled Tubes. ROBERT C. KINTNER. Ind. Eng. Chem.—Anal. Ed. **14:** 261 (Mar. '42). Meters described, operating on principle of variable area for flow, as does rotameter, easy to construct and inexpensive. Ranges were 150 to 2400 lb. of water per hr., but can be varied, and accuracy was 1 to 3% of vol. of fluid flowing. Method depends on height, during flow, of suitable float moving in metal tube with parallel-sided or V-shaped slots through which water emerges into annular space between pipe and glass jacket, re-entering pipe through above slots and through large holes provided. Behaves like variable-sized orifice. Calibration data shown for solns. of various viscosities, and correlation with Schoenborn-Colburn equation discussed. Constr. details given.—*Selma Gottlieb.*

CHEMICAL ANALYSIS

Provisional pH Values for Certain Standard Buffer Solutions. ROGER G. BATES, WALTER J. HAMER, GEORGE G. MANOV & S. F. ACREE. J. Res., Natl. Bur. Stds. **29:** 183 (Sept. '42). For use in calibration of electrometric pH assemblies, 17 std. buffer solns. investigated and pH values at 20°, 25° and 30°C. assigned to them. pH values of solns. range from 2.27 to 11.68, considered accurate to ±0.02 pH unit. Hydrogen-silver-chloride cells without liquid junctions used for establishing precise pH values of buffer mixts. Assumptions made to det. activity coefs. of the ions in the mixts. discussed. Method of assigning accurate pH value to buffer mixt. outlined. Directions for prepg. mixts. from purified anhydrous salts, std. solns. of acid and alkali and pure water given. Changes of temp. have larger effect on pH of buffers of pH greater than 7 than on those of acid buffers. In all cases, effect of diln. small; error of 1% in vol. of solvent added results in change of less than 0.001 pH unit. Use of pH meter of glass-electrode-calomel-electrode type, calibrated by means of std. buffer may often involve greater uncertainties than those inherent in

pH assigned to buffer mixt. Should be recognized that errors arising from liquid junction, hysteresis, temp. and salt effects may combine to give uncertainty of 0.01 and 0.03 unit or more in practical pH tests.—*Ed.*

Standardization and Stability of 0.1 *N* Sodium Thiosulfate Solutions in Hot Weather. SIGURD O. RUE. Ind. Eng. Chem.—Anal. Ed. **14:** 802 (Oct. '42). Dichromate procedure developed which gives highly accurate results in standardizing 0.1 *N* $Na_2S_2O_3$ solns. in hot weather at temps. of 23–40°C. Accurately weigh 0.2 to 0.22 g. purified $K_2Cr_2O_7$ into 500-ml. Erlenmeyer flask, dil. to 125 ml. with distd. water and add 5 g. KI low in iodates. Rotate flask to dissolve KI, add 5 ml. of 6 *N* HCl with const. swirling. Carefully wash down sides of flask to form layer of water on top of soln. Stopper flask and place in dark for about 6 min. Add 165 ml. distd. water. Titrate with 0.1 *N* $Na_2S_2O_3$ until soln. becomes greenish-yellow, rotating flask so that no excess $Na_2S_2O_3$ in contact with acidic soln. at any time. Add 0.6% starch soln., using from 2 ml. at 20° to 3 ml. at 40°C. Wash down sides of flask and continue titration to end-point. About 45 ml. of 0.1 *N* $K_2Cr_2O_7$ may be used instead of weighed portion. Accuracy within 0.07% in temp. range studied as compared with iodine method. Max. variation in normalities of untreated $Na_2S_2O_3$ stored 4 mo. at 20 and 40°C. was 0.3–0.4%. Chloroform and mercuric iodide most effective preservatives studied, effective for only 2 mo. at 40°C. At that temp., NaOH and Na_2CO_3, instead of acting as stabilizers, actually accelerated decompn.—*Selma Gottlieb.*

Stable Sodium Thiosulfate and Starch Solutions. JACOB EHRLICH. Ind. Eng. Chem.—Anal. Ed. **14:** 406 (May '42). A 0.1 *N* $Na_2S_2O_3$ soln. with titer unchanged approx. 5 mo., readily prepd. by using 0.05% NaOH and 0.1% Na benzoate as preservatives. Stable starch soln. made with 0.6% soluble starch, 0.1% NaOH, 0.3% KI and 0.1% Na benzoate. In iodometric titration, 1 ml. sensitive in 200-ml. vol.—*Selma Gottlieb.*

Measuring the Specific Surface of Particulate Substances. DANIEL SMITH & HENRY GREEN. Ind. Eng. Chem.—Anal. Ed. **14:** 382 (May '42). Specific surface of particulate substances, such as pigments and carbon blacks, detd. in simple manner by manometric measurement of water vapor adsorbed from satd. air at atm. pressure. Results in most cases check well with photomicrographic methods.—*Selma Gottlieb.*

Studies of Sewage Purification. *XVI. Determination of Dissolved Oxygen in Activated Sludge-Sewage Mixtures.* C. C. RUCHHOFT & O. R. PLACAK. U.S. Pub. Health Rpts. **57:** 1047 (July 17, '42). Inhibiting reagent composed of sulfamic acid, acetic acid and copper sulfate proposed. Reagent about twice as effective as copper sulfate alone, though contg. only half of original concn. of this salt. Consequently does not interfere with end-point in iodine titration. When activated sludge contacts reagent, O_2 absorption stopped, nitrites destroyed and sludge coagulated. D.O. may then be detd. upon sepd. supernatant by applying short Winkler procedure using sodium azide in alk. iodide soln. Detn. of D.O. in activated sludge mixtures by this procedure simple, dependable and specially valuable in operating practice.—*Ralph E. Noble.*

Electrolytic Solution of Sodium Hypochlorite. JAMES CAREY. Pharm. J. **149:** 62 ('42). Cause of instability discussed. Total available Cl detd. as follows: To 10 ml. unstabilized product add 1 g. NaI and acidify soln. with AcOH. Titrate liberated I with 0.1 *N* $Na_2S_2O_3$. 1 ml. latter = 3.546 mg. Cl. Combined Cl: To 10 ml. unstabilized product add 40 ml. 0.1 *N* HCl. Heat soln. to bp. and maint. at this temp. until Cl dispelled. Titrate cooled soln. with 0.1 *N* NaOH. 1 ml. 0.1 *N* HCl = 3.7 mg. NaOCl = 3.546 mg. Cl. Difference between values for 2 detns. is measure of uncombined Cl. Electrolytic soln. stabilized by adding to each 9 parts of soln. contg. 1.1% NaOCl, 1 part soln. contg. 0.5% NaOH in 18% NaCl soln. or 1 part soln. contg. 4% Na_2CO_3 in 18% NaCl soln.—*C.A.*

The Determination of High Chlorine Residuals. N. S. CHAMBERLIN. W. W. & Sew. **89:** 11: 496 (Nov. '42). 3 essential reactions involved between ortho-tolidine and chlorine. Meriquinones formulated only above pH 1.8 and colors developed unstable and variable according to pH and to gravimetric ratio of *o*-t. and chlorine. These more indicative of amt. of *o*-t. present than chlorine. Holoquinones formed when pH of mixt. less than 1.8. Familiar yellow or brown color produced in less than 4 min. Excessive *o*-t. does not affect colors but gravimetric ratio must not be less than 3 : 1; otherwise orange to red colors

produced. Most reliable reaction, since pH of mixt. generally reduced below 1.8 by H_2SO_4 added to *o*-t. and deficiency in amt. of *o*-t. recognized by orange or red color. Third reaction, forming chlorine-substituted holoquinones occurs when gravimetric *o*-t. to chlorine ratio 1 : 1 or slightly less. Red color formed merely indicates 1 : 1 ratio attained. To accomplish this, analyst must know chlorine residual beforehand. To assure pH of less than 1.8 for holoquinones when 1 ml. of *o*-t. soln. added to 100 ml. chlorinated water, 20% concn. of H_2SO_4 should be used (instead of *Standard Methods* 10%). Under present *Standard Methods* detn. for chlorine residuals of 1.0 ppm. or less, highest residual involved is 3.33 ppm. with min. *o*-t. chlorine ratio of 3 : 1; for residual detn. of from 1.0 to 10.0 ppm. highest residual 16.66 ppm. Gravimetric ratio of *o*-t. to chlorine of at least 3 : 1 assured by drop diln. method or equal vol. method. In drop diln. method usual quant. *o*-t. mixed with known vol. distd. water (Vol. A). High-chlorine-residual water added by drops of known vol. (Vol. B) until color of mixt. can be compared to permanent stds. going up to 1.0 ppm. Residual calcd. from: (Vol. A & B) × ppm. Cl matched = value of unknown, in ppm. Cl, in Vol. B. Equal vol. method involves using same vols. of chlorinated water and *o*-t. soln. with acid strength of 10% by vol. Simpler method for prepg. *o*-t. solns. using *o*-t. dihydrochloride described. —*F. J. Maier.*

Orthonitrosophenol as a New Reagent in Colorimetric Analysis. *Determination of Divalent Iron.* GEORG CRONHEIM & WILLIAM WINK. Ind. Eng. Chem.—Anal. Ed. **14:** 447 (May '42). Orthonitrosophenol (ONP) forms strongly colored compds. with no. of metal ions. Compds. distinguished by color and soly. in different solvents. Only divalent iron forms green, water-soluble complex with ONP. *Procedure:* Nearly neutralize soln. (spot test with methyl orange or bromophenol blue) and dil. to contain not over 1 μg. of Fe^{++} per ml. Mix 50 ml. in separatory funnel with exactly 5 ml. of acetate buffer of pH 5.2. Add 5 ml. of ONP soln., shake vigorously 15 to 20 sec. and allow to separate. Remove upper layer with pipet with rubber bulb and treat with second 5-ml. portion of ONP soln. Upper layer should still show yellowish green due to excess ONP. Filter water soln. into 30-ml. cell of photoelec. colorimeter and compare results with calibration curve. Ferric iron interferes but may be elimd. by citrate buffer soln. Anions such as PO_4 which form complexes with Fe^{++} must be absent. Sensitive to 0.01 ppm. of Fe^{++}. ONP prepd. in petroleum ether soln. by method of Baudisch (J. Am. Chem. Soc. **63:** 622 ('41) and Science **92:** 336 ('40)). Exact concn. cannot be prescribed but reagent must be controlled by following tests made at regular intervals: (1) For purity: After shaking 1 ml. of ONP soln. with 5 ml. of 1% copper sulfate soln. in test tube, petroleum ether should be absolutely colorless. (2) For sufficient concn: After shaking 2 ml. of ONP soln. with 5 ml. of $CuSO_4$ soln. (10 mg. of $CuSO_4 \cdot 5H_2O$ in 1 l. of distd. water) water soln. should be violet while upper layer should remain yellowish green. Results check well with gravimetric detns. Has been used for detn. of iron in Saratoga mineral waters.—*Selma Gottlieb.*

Elimination of Fluoride Interference in Molybdenum Blue Reaction. L. T. KURTZ. Ind. Eng. Chem.—Anal. Ed. **14:** 855 (Nov. '42). Addn. of boric acid elims. F removal in PO_4 detn. and does away with necessity of evapg. with $HClO_4$ to remove F. To aliquot of unknown soln. contg. less than 0.015 mole of F in test tube, add 15 ml. of 0.8 *M* H_3BO_3. Make up to 35 ml. with distd. water and add reagents to final vol. of 50 ml. according to method of Dickman and Bray. Max. color development less rapid in presence of H_3BO_3. Photometer readings should be made 5–10 min. after addn. of reagents. No separate calibration needed for H_3BO_3 addn. for F between 0.02 to 0.6 mole/l. (380 to 11,400 ppm.). —*Selma Gottlieb.*

Rapid Volumetric Method for Determination of Sulfate Ion. MERLE RANDALL & HENRY O. STEVENSON. Ind. Eng. Chem.—Anal. Ed. **14:** 620 (Aug. '42). Sulfate detd. by pptn. with known excess of $BaCl_2$ followed by titration of excess Ba with Na_2HPO_4 in presence of alcohol. Approx. 0.05 *M* $BaCl_2$ of known concn. added in excess with mech. stirring to acidified soln. of unknown sulfate at approx. 0.05 *M* (4.8 g./l. of SO_4). Without filtering, soln. neut. to methyl red (0.1% in 95% alcohol) and 1 drop of std. 0.1 *M* HCl added. Alcohol added to ensure final soln. contg. more than 27.5% by vol. Excess $BaCl_2$ titrated with approx. 0.05 *M* Na_2HPO_4 of known concn. to permanent yellow endpoint of methyl red. Na_2HPO_4 std. against $BaCl_2$ without addn. of SO_4, and SO_4 in sample

computed by diff. For soluble sulfates, 10 min. required for completion. Titration best done in white porcelain casserole. For quant. involved (0.025 to 0.06 g. of SO_4 in 20 ml. vol.) results within 0.5% of gravimetric results.—*Selma Gottlieb.*

Colorimetric Method for Phosphates. L. S. STOLOFF. Ind. Eng. Chem.—Anal. Ed. **14:** 636 (Aug. '42). Studies on optimum conditions of pH and color transmission in molybdenum blue method for PO_4 led to development of modified procedure. In 25-ml. flask, place aliquot of sample up to 15 ml. contg. not over 0.3 mg. of P. If less than 10 ml., make up to 10 ml. with distd. water to prevent pptn. of phosphomolybdic acid. Add in following order, mixing well after each addn. (Mohr pipettes may be used): 2 ml. of ammonium molybdate soln. (5 g. per 100 ml. of 1 *N* H_2SO_4); 2 ml. of hydroquinone soln. (0.5 g. per 100 ml. of distd. water made slightly acid with 1 drop of concd. H_2SO_4); and 2.5 ml. of Na succinate soln. (20 g., anhydrous basis, per 100 ml. of distd. water). Make up to 25 ml. with distd. water and measure color at 460 mμ within 4 hr., as succinate may crystallize out since pH near its isoelec. point. Instead of Na succinate buffer, 3 ml. of 20% Na_2SO_3 soln. may be used. Na succinate preferred because more stable than sulfite over long periods of storage. Effective range 0 to 0.35 mg. of P. Observed color stability thought due to occurrence in isoelec. range (pH 4.8 to 4.9) of both phosphomolybdate and molybdate where reactivity is at min. If hydroquinone added after buffer, no reaction.—*Selma Gottlieb.*

Colorimetric Determination of Small Amounts of Metaphosphate and Pyrophosphate. HENRY E. WIRTH. Ind. Eng. Chem.—Anal. Ed. **14:** 722 (Sept. '42). Since small amts. of meta- and pyrophosphates used in water treatment to control scale formation, method needed for detg. 0.01 to 5 ppm. to assure maintg. suitable concns. at all parts of treated systems. Use made of interference by meta- and pyrophosphates in reaction between thiocyanate and ferric iron. Iron in portions of sample and std. detd. by adding 5 ml. of aluminum nitrate reagent and 5 ml. of 20% ammonium thiocyanate soln. to 90-ml. samples and comparing with known stds. prepd. with distd. water and similarly treated. To make aluminum nitrate reagent, dissolve 200 g. of $Al(NO_3)_3 \cdot 9H_2O$ in 200 ml. of water and add 15 ml. of 20% ammonium thiocyanate. Extract 3 times with 75-ml. portions of 5 to 2 isoamyl alcohol-ether. Add 200 ml. concd. HNO_3 and warm soln. until ammonium thiocyanate completely decomposed. Cool and dil. to 500 ml.) On separate samples, det. amt. of 0.5 *N* HNO_3 needed to give pH 3.0 in 90-ml. portions treated with 5 ml. of ammonium thiocyanate and amt. of iron to bring concn. up to 0.2 ppm. Use glass electrode or suitable indicators. To 90-ml. portions of the metaphosphate- and pyrophosphate-free water add 0, 0.2, 0.4, 0.6, 1.0, 1.5 and 2.0 ml. of std. sodium metaphosphate (0.100 g./l. or same concn. of sodium pyrophosphate, enough iron std. to give total concn. of 0.2 ppm., HNO_3 to give pH 3.0 to final soln. and 5 ml. of 20% ammonium thiocyanate soln. Dil. solns. to 100 ml. 90-ml. samples to be tested are treated with iron std. to give 0.2 ppm. of iron, HNO_3 to pH 3.0 and 5 ml. of ammonium thiocyanate. After 5 min., colors compared with stds. 100-ml. Nessler tubes may be used for comparison, though increased sensitivity obtd. by extracting solns. with 15.0 ml. of 5 to 2 isoamyl alcohol-ether, removing 5.0 ml. of extract, adding 0.5 ml. of acetone and detg. percentage transmittance with photoelec. colorimeter. For larger amts. of metaphosphate, iron concn. adjusted to 2 ppm. and 5 ml. of 6 *N* HNO_3 added to stds. and unknown. Extraction not necessary. Monovalent positive ions commonly found in waters do not interfere; divalent positive ions interfere appreciably and aluminum has very pronounced effect. For this reason, stds. should not be prepd. from distd. water, but from metaphosphate- and pyrophosphate-free water of same compn. as that to be tested. Water previous to treatment with conditioning agent can be used, or treated water can be acidified and boiled for several hr. to convert meta- and pyro- to orthophosphate which does not seriously interfere. Aluminum-ion concn. should not be over 0.1 ppm.—*Selma Gottlieb.*

Accurate Determination of Calcium Without Reprecipitation. WILBUR H. MCCOMAS JR. & WILLIAM RIEMAN III. Ind. Eng. Chem.—Anal. Ed. **14:** 929 (Dec. '42). Soln. should contain preferably about 2 millimoles Ca (80 mg.). If Fe or P present, soln. should contain enough HCl to prevent formation of ppt., but large quants. of acid should be avoided. Add 12 ml. of 2 *M* formic acid, dil. to 140 ml. and heat to 95°C. Add, with stirring, 20 ml. of

0.5 *M* oxalic acid through funnel with stem constricted so that about 85 sec. required for addn. Rinse funnel with 2 ml. water. Digest at 85–90°C. for 5 min. Cool to 25°C. in 15 min. in larger vessel of cold water, then add, with stirring, 34 ml. of 2.0 *M* ammonium formate through same funnel. Rinse funnel with 5 ml. water and digest ppt. 30 min. at 25°C. Filter through asbestos mat on perforated porcelain disk in funnel. Wash ppt. 3 times by decantation with 20 ml. wash soln. (0.020 *M* with ammonium oxalate and 0.01 *M* with oxalic acid); transfer ppt. to filter, using total of about 150 ml. wash soln. Finally, wash ppt. and funnel with three 8-ml. portions water. Transfer ppt. with asbestos and porcelain disk to 400-ml. beaker and titrate with std. permanganate according to method of Fowler and Bright. Stir soln. occasionally for 5–10 min. after addn. of H_2SO_4 before starting titration. Not recommended for very low concns. of Ca. Minor variations of pH from 3.70 have no effect. Interference of moderate amts. of Al, Fe, Mg, Mn, PO_4, Na and Ti negligible, though in presence of PO_4, weighing of ppt. preferred to titration with permanganate. Calcium may vary from 0.5 to 4.0 millimoles (20 to 160 mg.).—*Selma Gottlieb.*

Determination of Calcium in Presence of Magnesium by Standard Soap Solution. J. W. Polsky & E. C. Feddern. Ind. Eng. Chem.—Anal. Ed. **14:** 644 (Aug. '42). Ca detd. in presence of Mg by direct titration with Clark's soap soln., using ammonium chloride and pH adjustment to prevent simultaneous pptn. of Mg. Measure 50-ml. water sample into 8-oz. glass-stoppered bottle and neut. to phenolphthalein. Add 1.0 ml. of 10% NH_4Cl and 2.7 ml. of 1 *N* NaOH, bringing pH to approx. 11.7. pH of 11.7 to 12.0 before titration allowable without affecting stability of end-point or accuracy of detn. Add std. soap soln. (1 ml. = 1 mg. of $CaCO_3$) in small portions from buret. Shake bottle vigorously after each addn., place on its side and observe formation of lather. This continued until lather formed which covers entire surface of liquid for 1 min. If more than 7 ml. required, aliquot dild. to 50 ml. with distd. water so that final end-point will require less than 7 ml. Ca content calcd. from: (ml of soap titrated − 0.20 ml.) $\times \frac{1000 \times 1.14}{\text{ml. of sample}}$ = ppm. of Ca as $CaCO_3$. Diff. between total hardness as usually detd. by Clark method and Ca as detd. above gives approx. hardness due to Mg. Ions usually found in ind. waters do not interfere. Max. error small and on par with std. soap method.—*Selma Gottlieb.*

Determination of Nitrites in Water by Means of Gentian Violet. A. Kh. Tariveryan & O. N Saakyan. Hig. i Sanit. (U.S.S.R.) *No. 9:* 51 ('39); Khim. Referat. Zhur. (U.S.S.R.) *No. 5:* 73 ('40). Color of gentian violet changes from violet to blue on reaction with HNO_2 in presence of AcOH. Velocity of reaction depends on amt. of nitrite. 0.001% gentian violet soln. used for detn. Limit of sensitivity 0.003 mg. of N_2O_3 per l. of water. Presence of HNO_3, NH_4^+, Fe^{+++}, Fe^{++}, Mn^{++}, Cl^-, SO_4^{--}, Ca^{++}, Mg^{++} and H_2S in water does not interfere with reaction. —*C.A.*

SOFTENING AND IRON REMOVAL

High-Speed Water Softening Process Makes Its Municipal Debut. Alex Van Praag Jr. Eng. News-Rec. **129:** 442 (Sept. 24, '42). New 70-gpm. water treatment plant of Teutopolis, Ill., consists of coke-tray aerator, "Spiractor" softening unit and 2 filters. Softener and filter operate under city pressure. "Spiractor" cold-lime softening process, invented by E. T. Zentner, consists of passing water and lime suspension upwards, and with spiral motion through conical tank slightly more than half-filled with granular (0.1–0.2 mm.) $CaCO_3$ catalyst, rate of flow being sufficient to keep latter in suspension. Insol. reaction products deposit on surface of granules in firmly adherent layers, and, as granules increase in size and bed increases in vol., larger granules withdrawn through drawoff valve at bottom and fresh material added at top. Granular material removed drains to less than 5% moisture in less than 24 hr. and can be handled like slightly damp sand. May be crushed and screened for re-use as catalyst or calcined for recovery of lime. As Teutopolis water contains considerable Mg, coagulant introduced with lime, as is also hypochlorite for sterilization. Hardness reduced from 271 to 76 ppm. and finished water stable. Reten-

tion in softening unit only 5–10 min. Plant part of complete new supply and distr. system, including wells, pumping station, 60,000-gal. elevated steel tank floating on system, c-i. mains, services and meters. Level of water in elevated tank controls starting and stopping of service pump and chem. feeds, thus permitting automatic operation. Cost of project $75,000.—*R. E. Thompson.*

Tests of Modern Base-Exchange Materials in Practice. K. HOFER. Progressus (Ger.) **6:** 424 ('41). Discusses softening of water with base-exchange materials. Fused zeolites have been used, but these attacked by waters contg. aggressive CO_2. More resistant zeolites later produced, and great advance made when non-siliceous exchange materials made, first from carbonaceous materials and later from resins. Materials resistant to acids and also to waters contg. considerable alky. (up to pH value of 9.5). May be used to treat waters at temps. up to 95°C., and may be regenerated with acids, or with an acid soln. of sodium chloride, contg. acid and salt in such proportions that when water concerned is softened, carbonate hardness converted to carbonic acid and permanent hardness to corresponding sodium salts. Comparative tests on use of Invertit, mineral base-exchange material, and Wofatit, synthetic resin, made at large plant. Raw water had high content of carbonate hardness, first treated with lime and filtered before treatment with exchange materials. Less than amt. of lime theoretically necessary added to avoid excess alkali in water. Exhausted base-exchange materials rinsed, regenerated with soln. of sodium chloride, and washed until content of chloride as low as that of raw water. In prelim. treatment with lime 190 cu.m. per hr. treated, and total hardness reduced from 18.2° to 6.4° (German). As less than theoretical quant. of lime added, magnesium hardness only slightly reduced. Filtered water colorless and clear, and no ppt. sepd. on standing. In tests on Invertit and Wofatit filters, soln. of sodium chloride with sp.gr. of 1.2 used for regeneration. Regeneration of Invertit filter took 40 min. and of Wofatit 2 hr. Materials regenerated when hardness of softened water increased to 0.1° (German). Anals. of waters softened by Invertit, Wofatit which had been in use for year, and Wofatit which had been in use for only few weeks given in a table. Exchange capac. of Wofatit greater than that of Invertit, and less water required for washing and regeneration. Immediately after filter regenerated, alky. of water increased as it passed through softener, but during softening run, alky. of softened water gradually decreased until finally less than that of water entering softener. Suggested that this is because in first phase, sodium ions in exchange material exchanged for hydrogen ions, and later hydrogen ions given up in exchange for sodium.—*W.P.R.*

Ion Exchange Between Solids and Solutions. H. F. WALTON. J. Franklin Inst. **232** 305 ('41). Review of various aspects of ion-exch. processes. Structure of various types of materials with ion-exch. properties discussed. For ions to pass in and out of mineral, certain openness of structure necessary. Some correlation between ion-exch. capac. and vol. per oxygen atom of alumino-silicate crystals. Zeolites, ultramarines and scapolites built up of tetrahedra linked together in such a way that channels left through crystal; these channels permit ready diffusion of ions through whole crystal. In montmorillonite, crystal unit consists of 2 layers of silicon and oxygen atoms with planar space between them. This space should permit free access of ions, but ionic replacement not as easy as in zeolites. For treatment of water, natural minerals largely replaced by synthetic alumino-silicates prepd. by fusing mixtures of quartz, clay and soda-ash or by mixing solns. of sodium silicate with sodium aluminate or aluminum sulfate. Pptd. type have higher base-exch. capac. and react more rapidly than fused alumino-silicates. Ion-exch. capac. increases with increase in ratio of silica to alumina up to 6 : 1, after which it falls slowly. Suggested that optimum ratio corresponds to interatomic spacing, in which permeability to ions and spatial and electrostatic requirements for holding replaceable ions in solid granules together produce max. exch. capac. Chief natural org. products with ion-exch. properties are humic acids and proteins. Much of ion-exch. capac. of soil due to humic acids. Commercial ion-exch. materials can be prepd. by treating carbonaceous materials with dehydrating agents, e.g., by treating coal with sulfuric acid. Structure of treated coal little understood; may contain graphitic acid, known to have ion-exch. properties. Synthetic resin exch. materials, prepd. from phenols and formaldehyde, have high potential exch. capac. but rate of reaction slow. Other resins with

higher rate of reaction developed recently. Colloidal particles suspended in ionizing liquid have double layer of elec. charge at surface; ions in outer layer can be displaced by other ions added to soln. Gels of aluminum and iron oxides used to remove fluoride ions from water by anion exch. in this way. Distr. of ions between cation exch. materials and solns. also discussed. In most cases one ion replaces another in equivalent proportions, but sometimes exch. of cations accompanied by adsorption or desorption of anions so that exch. not exactly equivalent. Equations proposed by various workers for expressing distr. of ions between solid and liquid discussed. In exch. between ions of equal valency, ratio of concn. of ions in exch. material depends only on ratio of concns. in soln., but when ions of different valencies concerned, proportion of ions of high valency in exch. material greater in more dil. solns. Ions of higher atomic weights held more firmly by exch. material, though hydrogen exception to rule, as it is as strongly absorbed as barium. Shown that amt. of swelling undergone by material in water affects base-exch. capac. of casein. Ungerer found that nature of anion affected exch. of calcium alumino-silicate with several different potassium salts, but other workers found that anion had no effect on cation-exch. equilibria. Water softening most important of technical applications of ion-exch. Factors affecting eff. of exch. between various pairs of cations discussed. There is an optimum rate of flow of liquid through granules; at high rates insufficient time for reaction, and at low rates flow not turbulent and liquid can pass granules without coming into contact with them. Possible to remove all electrolytes from water by passing water through hydrogen-exch. material and then through bed of acid-absorbing material. Exch. materials also used in water treatment for removing small quants. of various materials, such as heavy metals, from water. Uses of ion-exch. materials for purposes other than water treatment summarized. Bibliography of 79 refs.—*W.P.R.*

Cation Exchange in a Carbonaceous Ion Exchanger. HAROLD F. WALTON. Trans. Ill. State Acad. Sci. **34:** 2: 124 ('41). Industrial type of exchanger formed by treating bituminous coal with H_2SO_4 or SO_3 satd. with $CaCl_2$ soln. and then shaken with NaCl soln. for 12 hr. In second run, same solns. used in the reverse order. Fact that graphs obtained for distr. ratios differ indicates that true equil. not reached. If exchange material had been used in previous run with same solns., ratios approached mean between the values obtained with freshly satd. exchangers. Concluded that characteristics of exchange body conditioned by ion with which material last satd. and do not change until material satd. or nearly satd. with another ion. With HCl and NaCl as solns., distr. ratio curves almost coincide, though definitely not linear. Distr. law does not hold in these cases.—*C.A.*

Coal for Water Purification. *Staff Report.* [DALE BOGARD.] Coal Age **47:** 10: 159 (Oct. '42). New field in water conditioning opened by "cation exchangers" prepd. from bituminous coal—first satisfactory method of prepn. of H exchange materials. Non-siliceous nature of exchangers from coal makes them particularly useful in softening hard boiler feed water and acid waters. In water treatment, cation may be Na, Mg or Ca. Electro-pos. in character, such cations, when combined with certain bodies called cation-exchangers, can be exchanged for electro-neg. anions such as carbonic acid (H_2CO_3), Cl, SO_4 or H. *How Exchangers Work:* Exchanger hands H over to bodies in water contg. anions, like Na-, Ca- or Mg-bicarbonate or chloride, taking contained Na, Ca or Mg in exchange. Thus, with Ca-bicarbonate, H unites with oxide of C, becoming a carbonate, H_2CO_3, while Na, Ca or Mg combines with exchanger as H partner leaves. Cation exchanger later restored by adding dil. acid, e.g., H_2SO_4, to provide H needed. Thus cation once more ready to work on other water. At same time, H_2SO_4 turns Na, Ca or Mg compds. to almost insoluble SO_4's which stay with exchanger and require rinsing out to restore condition. Water thus purified passes off, contg. only anions, H_2CO_3 and Cl. H_2CO_3 decomposes into water and CO_2 removed in degasifier. As result, water considerably demineralized and cation exchanger ready to work on other water; e.g., $H_2 \cdot \text{coal} + Ca(HCO_3)_2 = 2H_2CO_3 + Ca \cdot \text{coal}$. $Ca \cdot \text{coal} + H_2SO_4 = H_2 \cdot \text{coal} + CaSO_4$. (Coal not raw but 14×20-mesh digested with concd. H_2SO_4 for some hr., washed, autoclaved with dil. NaOH). Cation exchanger will combine with H when regenerated with dil. acid and with Na, when in NaCl soln. High Na content of raw water temporarily decreases capac. of carbonaceous H exchanger. Secondary exchange mechanism between Na and H exchanger does not occur when raw water contains Na. Dil. solns. of Cu ions

that otherwise would be wasted can be concd. on carbonaceous exchanger and removed with small vol. of regenerating acid. Active chars suitable for removing odors and tastes from potable waters prepd. from coal or coal refuse. —*Ralph E. Noble.*

Reduction of Mineral Content in Water With Organic Zeolites. R. F. GOUDEY. Proc. A.S.C.E. **68:** 225 (Feb. '42). (*Abstracted,* Jour. A.W.W.A. **34:** 779 ('42).) *Discussion. Ibid.* **68:** 625, 841 (Apr., May '42). ROBERT SPURR WESTON: Seems fanciful that there are durable, org. cation exchanging zeolites on market which will remove hardening carbonates and bicarbonates in form of CO_2 gas and which may be regenerated with H_2SO_4, which, when combined with Ca, is superlative water hardener; or that there are anion exchangers which will remove not only bicarbonates but sulfates, chlorides and fluorides, with increased acidity of effluent, and which require NaOH for regeneration. Interesting indeed is showing that hydrogen zeolites may be used to remove either Ca or Mg, or both, and that both hydrogen and sodium cycles may be used on portions of same water and the two mixed afterward. HARVEY F. LUDWIG AND RUSSEL G. LUDWIG: Colloid chemists have detd. that ion exchange properties of zeolitic material in aq. suspension result from existence of elec. double layer surrounding nucleus or core of each particle. Degree to which a particular ion will be held or adsorbed by inner layer termed "exchange adsorbability." Magnitude of this varies inversely with hydrodynamic size of ion and directly with valence. Cations commonly found in natural waters may be classified in increasing order of exchange adsorbability as follows: Na^+, K^+, Mg^{++}, Ca^{++}, H^+, Fe^{+++} and Al^{+++}. If ions in dispersion medium other than those of diffused outer layer, then phenomenon of adsorption exchange will occur, in which ions initially present in outer layer displaced by those from dispersion medium. Mechanism of adsorption exchange has multitude of other applications of interest to civil engr. In flocculation of turbid waters, phenomenon particularly important, in that stability of suspended turbidity (clay) particles results largely from zeolitic properties. Another important application of ion exchange principle found in study of soil corrosion of pipes. Phys. and chem. properties of soils generally controlled by magnitude and nature of soil colloids, although these usually only fraction of soil mass.—*H. E. Babbitt.*

The Use of Lignin for Removal of Iron From Water. G. H. NELSON & S. I. ARONOVSKY. Paper Tr. J. **113:** TAPPI Sec.: 239 ('41). Disadvantages of presence of iron in water and methods of removal discussed. Lignin found to be efficient for removal of iron either in ferrous or ferric state from natural water or from waters to which iron had been added; in these expts. very pure lignin used. Further expts. made on use of crude lignin for removing iron from water and on removal of color which crude lignin imparts to water. Prepn. of lignin of 89–92% purity described. Samples of water tested were tap water, to which added 20 ppm. ferrous chloride, and raw water from deep wells contg. about 9 ppm. iron. In first series of expts. water stirred for 1 hr. at room temp. with 16-500 ppm. lignin; samples then filtered through coarse filter paper, or filtered through sand, or treated with alum and filtered through sand after adjustment of pH value to 5.5. Most successful method for removal of color by treatment with alum followed by filtration through sand. Percentage of iron removed varied from 84.6 to 99.7. Capac. of crude lignin for removing iron from tap water contg. ferrous chloride compared with that of pure lignin. With pure lignin, only slight increase in eff. achieved by increasing amt. of lignin used, but with crude lignin amt. of iron removed increased with increase in amt. of lignin used. Second series of expts. made using filters of different depths of corncob pulp impregnated with lignin; mixt. contained 19.8% lignin on dry basis. Water applied either intermittently or continuously to filters. Filters backwashed at regular intervals and when clogged cleaned with 4% hydrochloric acid. Intermittent application of water gave higher removal of iron, but final water more colored than with continuous application; less clogging occurred when application intermittent. Color of effluent decreased as filters remained in operation, probably due to decrease in content of colloidal lignin. Expts. showed that corncob pulp removed about 37% of iron; corncob pulp soon became gelatinous mass through which water could not pass. In third series of expts. water applied intermittently to filter of sand impregnated with lignin. Removal of 95–99% of iron obtained. Effluent from filter highly colored at first, due to presence of lignin removed from sand, but color much reduced after 80 l. of water had passed through filter. Different rates of application of water studied; slightly higher percentage removal of iron obtained at high rate (0.53 gal. per sq.ft. per

hr.) than at low rate (0.27 gal. per sq.ft. per hr.). Expts. on sand filter which had not been impregnated with lignin showed that only 8–19% of iron removed by sand alone; effluent highly colored. Concluded that lignin may be useful for removing iron from water, but further studies on plant scale necessary.—*W.P.R.*

Water Softening at Twin Cities Plants. *A Symposium. Experience With St. Paul Softening Plant.* L. N. THOMPSON: Original St. Paul treatment plant, constructed in '20–'21, typical rapid sand filter. Softening plant constructed in '39–'40. Water enters plant through 60" and 48" c-i. conduit into over-and-under type mixing chambers, passes to new flocculator chamber, splits and flows to two clarifiers, through recarbonation chamber, to two old coagulation basins now used as secondary settling basins. Then flows to 18 filters, thence through 6 clear wells lying directly under filters, to pumps for distr. to one of several large storage reservoirs in distr. system. Plant can very readily be converted to old std. filter type by elimg. use of lime and CO_2 gas. Approx. 8½ bil.gal. water is treated annually. *Purification and Softening at Minneapolis.* J. A. JENSEN: Chlorination of water supply for Minneapolis initiated in '08, and, in '13, filtration begun at Columbia Hts. In '27, second plant located at river near Fridley placed in service. These plants now provide 50 mgd. to 500,000 people. Salient points of softening devices consists of precipitator-type basins employing features afforded by cone-form reaction chamber now well known to water works men. Chem. treatment designed to produce finished water hardness of about 75 ppm. and to reduce color to not more than 15 ppm. Public reaction to softened water gratifying.—*H. E. Babbitt.*

Removal of Iron From Water by Means of Half-Calcined Dolomite (Magnomasse). S. A. VOSNESSENSKI, A. V. JEVLANOVA & R. V. SUVOROVA. Zh. Prikl. Khim. (U.S.S.R.) **13:** 1304 ('40); Chem. Zbl. (Ger.) **2:** 1892 ('41). Removal of iron from water by filtration through half-calcined dolomite ($CaCO_3 \cdot MgO$) investigated. Artificially prepd. solns. of ferrous sulfate and naturally occurring moorland waters used. Results obtained in agreement with equation $H = Kd^n \sqrt{I} \log (C_0/C)$, where H equals depth of filter, in cm., required to reduce content of iron to concn. C expressed as mg./l.; C_0, original concn. of iron in untreated water in mg./l.; I, rate of filtration in m. per hr.; d, diam. of particles of dolomite in mm.; and K and n empirical constants. Any iron remaining in water after filtration through calcined dolomite can be removed by filtration through sand. Process can be used for treatment of water contg. iron in form difficult to remove.—*W.P.R.*

DISTRIBUTION SYSTEM—CONSTRUCTION AND MAINTENANCE

Augusta, Georgia, Lowers 30-Inch Cast-Iron Water Main by Melting Blocks of Ice. JOHN D. TWIGGS. Cast-Iron Pipe News. **8:** 4: 2 (Oct. '42). Augusta, Ga., lowered 30" c-i. main under water pressure while resting on 200-lb. melting ice blocks. Connecting west reservoir with filter plant, main ran southeast from former to 45° bend, then east to latter. Portion from bend east found too high at bend and either side for proper grading of street. Required lowering 26" at highest point while under 22 psi. pressure. Profile els. showed irregular 3% gen. grade, with part involved on vertical arc 400′ long with high point 14" above strait grade. Being under pressure, essential to lower main slowly to prevent springing lead joints. Excavated section under each pipe length to required grade, leaving 3′ earth-plug under each bell. Ice blocks placed under each joint in hole excavated and tamped up to pipe as tightly as possible. All dirt under bells removed by 2 men, one on either side of each, digging immediately under pipe just enough to allow ice to take load. When ice seen safely carrying load, all dirt removed and pipe settled as ice melted. Highest temp., 94°; operation completed between 9 A.M. and 8 P.M.; 3900 lb. of ice used; and no leaks developed. History of Augusta and water supply detailed.—*Ralph E. Noble.*

Notes on Steel Mains and Main Laying. E. F. BLACKBOURN. Wtr. & Wtr. Eng. (Br.) **45:** 101 (Sept. '42). Earliest record of use of c-i. pipe in London area refers to laying of short length of 12" main by Chelsea Water Works Co. in 1746. By 1810–20 London area abandoned entirely use of other materials and adopted c-i. pipe. Early type wood joint did not last long, being superseded by lead joint,

which developed quickly into form well-known today. Principles covering laying and jointing pipes have changed but little during last 130 yr. During last 20 yr., supremacy of c-i. pipes for gen. use challenged by lap-welded steel pipe with bituminous protection. Use of bitumen lining and sheathing calls for special attention to methods of handling and storing pipes. Sheathing of joint is completed with aid of light metal mold placed around pipe to cover gap in sheathing. Hot bituminous mixt. poured into mold and allowed to set. Completion of internal lining at joint more difficult and cannot be done by using mold. Done by spreading thick layer of hot bitumen-asbestos over bottom of socket and keeping mixt. plastic while pipe pressed home to final position. When length of main completed and tested, necessary to exam. lining for defects. All depressions should be filled in and resurfaced. Cracks should be cut out and damaged portion replaced with new material. Large steel pipes are mfrd. by taking suitably sized plates, bending to tubular form and welding overlapping edges, which are feathered for purpose. Special pipes are built up from straight pipe stock by cutting and welding. Elec. welding preferred to gas welding. General form of transverse joint for welding consists of plain socket and spigot, joint being made by welding at face of socket and, inside pipe, at end of spigot. Most satisfactory lead joint for steel pipes appears to be cold strip lead joint. Form of steel socket used for lead jointing follows closely on that used in c-i. pipe. Sockets should be carefully examd. for splits after joints have been made, especially in vicinity of longitudinal weld. Collars and collar joints require careful consideration. Difficulty with collars is to provide adequate clearance and, at same time, provide for complete filling of joint space with lead, yarn or bitumen. From observations of effects of falling bombs, concluded that steel shows little or no effect from shock, such as is seen in c-i. pipes. Effect on bitumen lining and sheathing surprisingly small. In fact, scarcely any damage observed could be attributed to this cause. No repair work appears necessary to lining and sheathing beyond limits imposed by repairs to damaged steelwork and calking of joints.—*H. E. Babbitt.*

Reinforced Concrete Pipe for Use Under High Internal Pressure. AARON SCHAPIRO. Bol. Obras Sanit. Nacion (Arg.) **10:** 6 (July '42). Difficulty in importing metal pipe for use in water supply projects has resulted in vigorous revival of local pipe-making industries. Of these, those producing asbestos-cement and reinforced concrete pipe have greatest practical importance. Since most of these industries are in exptl. stage, results of mfrd. products not uniformly satisfactory. Small diam. asbestos-cement pipe of excellent qual. and capable of resisting high pressures has been mfrd. On other hand, results obtained with this type of pipe over 0.40 m. in diam. generally disappointing. Reinforced concrete pipe installations have given all sorts of contradictory results in practice. Although mech. mfg. aids, such as vibration and centrifugation, have helped toward improvement of pipe qual., there are little understood factors of design and curing which should be evald. before a product of uniform dependability can be obtained. Author believes direct application of std. reinforced concrete design formulas to design of reinforced concrete pipe not conducive to proper utilization of materials. For instance, use of 15 for value of n (ratio of modulus of elasticity of steel in tension to that of concrete in compression) does not seem logical for structures in which both materials are subjected to tensile stresses. Instead, value of n in neighborhood of 38 would be more in keeping with stresses to be met. In regard to concrete curing practice, author believes drastic change in environmental conditions, produced by removal of pipe from curing tanks after initial setting, harmful to concrete. Better results obtainable from continuous exposure to const. temp. and moderately damp atmosphere from time of mfr. to time of use. Another criticism of existing specifications is directed to requirement that pipe must withstand initial pressure 1.5 times that of max. anticipated service requirements. Since full strength of concrete not acquired until after complete curing, this requirement leads to uneconomical proportioning of materials in order to meet high early strength test. For gravity lines operated by slow-closing gate valves, where water hammer need not be considered, test pressure equal to max. anticipated believed ample. Gradual increase in pipe strength after installation would furnish desirable factor of safety. Recommendation made that lab. expts. be undertaken to det. extent to which above-mentioned factors influence behavior of reinforced concrete pipe under actual working conditions and to point out other improvements in design and mfr. resulting in more dependable performance and better use of concrete and steel.—*J. M. Sanchis.*

Economy of Tin-Lead Pipe Jointing. ANON. [GEORGE JENNINGS.] Wtr. & Wtr. Eng. (Br.) **45**: 107 (Sept. '42). Newly devised method of jointing consists of shaping pipe ends to suitable male and female cones. Male cone then wrapped with double layer of pre-fluxed tin-lead alloy foil and joint assembled and heated with blow lamp until foil melts, thus sweating surfaces together. Two pieces of ½" bore by 7 lb. per yd. lead pipe used. Whole joining operation took less than 4 min. Tests demonstrated that std. ½" pipe can be joined with 0.05 oz. of tin-lead alloy with complete safety and substantial saving of time. Saving of about 99% of solder commonly used.—*H. E. Babbitt.*

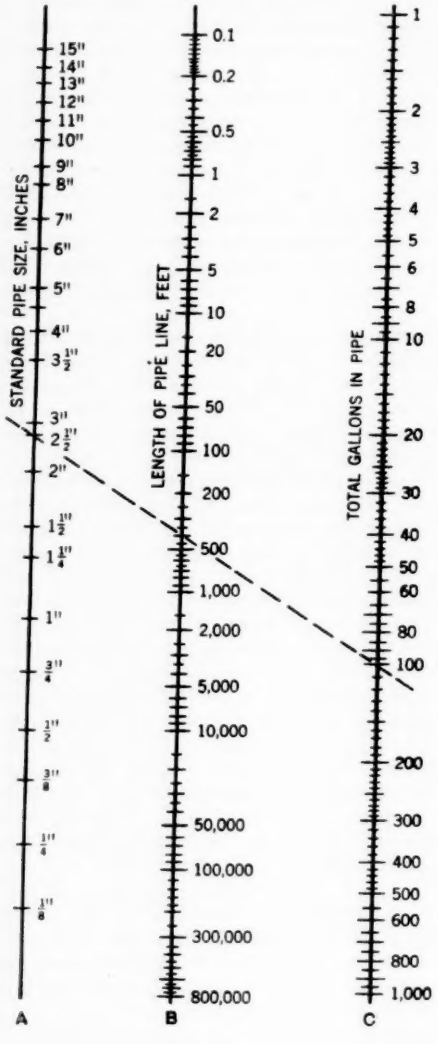
Making Emergency Repairs of Wood Pipe With Concrete. B. C. GOSNEY. Pacif. Builder & Engr. **48:** 10: 29 (Oct. '42). 12" wood pipe section failed for 6' distance. To repair, exposed full length of broken section leaving 4" clearance beneath. Cut 6" wide galvanized sheet metal, length of defect. ½" coupling soldered into ½" hole drilled at center. Metal formed pocket for leakage, protecting concrete being placed. Plate held in position with haywire around pipe at 1' intervals. ½" pipe then inserted into sleeve extending upward 18". Shut-off valve at top end left open. Pipe to relieve pressure from leak until concrete set. 1–2–3 concrete mixture poured into 5" annular space between pipe and form. Because of 85 psi. continuous pressure on line, reinforcing steel used liberally. Leakage allowed to escape through ½" line 10 days, then shut-off valve closed. 8 yr. after, staves practically gone but concrete patch showed no leakage. In such repair concrete should be tamped well and extended beyond lead in all directions, preferably, collar to collar.—*Ralph E. Noble.*

Wood Manhole Covers Being Used as Wartime Substitute. ANON. Western City **18:** 12: 34 (Dec. '42). Los Angeles county officials designed pressure-treated wood manhole cover and concrete frame, saving approx. 500 lb. of metal. Made with laminated wood strips fashioned hexagonally or circularly. Plans call for nailing 2" × 4" × 8" laminated strips with four 20-penny nails to each strip, and running at least two ⅜" bolts through all members, countersinking both bolt ends. Where difficult to get nails and bolts, use wood dowels and waterproof glue. Cost of covers will vary according to locality. Lumber yards in Los Angeles area make them at low price because possible to use short pieces otherwise discarded. Hexagonal cover 37½" in overall diam., 32½" between opposite faces. Latter, 18¾". 2 lifting slots, each 3" × ¾", set in 8" from opposite corners. Wt. of metal-bound cover approx. 130 lb.; glued-in dowel cover, slightly less. Lumber required, 63.3 fbm. of No. 1 common Wolmanized or creosoted Douglas fir. Frame uses 0.14 cu.yd. of class A concrete. Two ¼" reinforcing rods used in concrete retainer, 1 in upper, 1 in lower section, inside perimeter. About 24' of rod needed for overlapping ends. 6 sides of cover faced with ¼" plywood when pouring concrete, to give ample space for expansion and contraction between cover and retainer. Circ. covers used as inside form by tacking roofing paper thereto for ¼" clearance. *Preservative treatment* of wood by pressure impregnation process specified because decay and termite attack at edges would seriously reduce safety and life of cover. Wear and splintering reduced by laying laminated strips at 45° angle to traffic line, applying thin coat of bitumuls or emulsified asphalt, covered with dry sand or pea gravel, to top surface and keeping cover surface flush with roadway.—*Ralph E. Noble.*

Water Main Cleaning in a Western Municipality. A. S. G. MUSGRAVE. Eng. Cont. Rec. **55:** 43: 28 (Oct. 28, '42). Oak Bay, B.C., community of 10,000, purchases water in bulk from adjoining city, Victoria. Water, derived from large mountain lakes in reserved watersheds, has pH value of 6.8. Complaints of inadequate pressure in certain districts necessitated replacement or cleaning of mains and when found that tuberculation had reduced avg. size of 4" mains in districts concerned to just under 3", decided to clean some 2 mi. of mains, mostly 4", with short sections of 6" and 8". Better than 3-fold increase in delivery from these mains effected. Machine and procedure employed described. Weekly flushing of hydrants found necessary for few weeks after cleaning to reduce discoloration of water. Interruption in supply during cleaning operation varied from 4 to 8 hr. in various sections. Entire cost about ⅓ cost of laying new 4" main and correspondingly less for 6" and 8" sizes.—*R. E. Thompson.*

A Good Kink for Locating a Leak or Stoppage in a Concealed Pipe. W. F. SCHAPHORST. Am. Gas. J. **157:** 1: 10 (July '42). To locate leak in steam, air, gas or water pipe: Fill pipe with water to overflowing. Close all valves holding water against gravity. Let

stand several hr. or overnight to permit max. leakage. Refill with measured vol. Calc. distance to leak thus: sq. inside diam. of pipe in in., multiply by 0.7854 and divide result into cu.in. vol. of water replaced. Quotient is distance to "trouble spot" in in. Leaks located with amazing accuracy, resulting in min. cost for repair work where piping concealed or stopped-up. Handy chart (*below*) helps det. no. of gal. in any pipe. Includes more than avg. conditions. All std. pipe sizes from $\frac{1}{8}$" to 15" in col. A; lengths from 0.1′ to 800,000′, col. B; vol. from 1 to 1,000 gal., col. C. To use, run straight line through pipe size (A) and no. of gal. to fill pipe (C). Intersection with (B) gives trouble-spot location. Example: $2\frac{1}{2}$" pipe (A) required 100 gal. (C); trouble 400′ away (B). Inversely, desiring to know no. of gal. in any pipe length, or pipe size to hold given no. of gal. within certain length limits, chart applied conveniently.—*Ralph E. Noble.*



Care and Maintenance of Elevated Tanks. Edward E. Alt. Internatl. Engr. **82:** 115 (Oct. '42). At one time vertical standpipe for water storage used, sacrificing approx. $\frac{2}{3}$ of lower storage capac. and utilizing only upper $\frac{1}{3}$ for gravity supply. Later, used flat-bottom steel tank on steel tower with chime beams. Chief objection, tank bottom covered by supporting joists, making it inaccessible for inspection and painting. Ellipsoidal-bottom tank now most popular, built with large-diam. steel center riser and water column, 4′ diam. for tanks under 250,000 gal., which by *tempered water circulation* protects against freezing. Tank proper of large-diam. and shallow depth reduces variation in pumping head thus giving more economical operation. Most elevated steel tanks of 500,000 gal. or more capac., all-welded constr. Designers' objective to reduce maint. costs by elimg. perishable wooden casings, mech. accessories, special equip., except bronze seat washout valve at bottom of large riser, and std. indicator gage-board with metal float. Recommend latter replaced by pos. static pressure gage in pumphouse; open and test washout valves every 6 mo.; carefully inspect and do necessary painting every 4 to 5 yr. On first painting: (1) thoroughly wire-brush and scrape all inside and outside surfaces, removing all loose scale with ball peen hammers; (2) spot-paint with red lead all steel surfaces so exposed; and (3) give inside 1 coat of red lead and outside 1 coat of black or bronze-green graphite or finish coat as desired. On subsequent paintings follow same procedure to elim. pitting or advanced corrosion. Inside tank painting most important. Paint mixtures, types and procedures discussed. Most recent contribution to steel water tank protection is cathodic protection system, which reduces maint. cost and keeps tank in continuous service. Ill. Dept. of Pub. Health requires sterilization of steel water tanks after erection or internal repairs or painting. Surfaces should be free from dirt, org. matter. Recommend sterilizing soln. contg. 50 ppm.

available Cl_2, contact period 5 hr. or preferably overnight, before placing tank in service. Best to test effluent for safe drinking qual. as check on sterilization effectiveness before permitting water use for drinking without boiling. —*Ralph E. Noble.*

Horizontal Stave Wood Tank. HARRY R. POWELL. Pacif. Builder & Engr. **48:** 10: 23 (Oct. '42). Hitherto, tanks and reservoirs made of steel plate or concrete, reinforced with steel rods or vertical wood staves having exterior steel bands to resist hydrostatic load. Horizontal wood-stave tank has staves horizontal, bent around tank, acting as tension bands and container for liq. Design saves $\frac{3}{4}$ of steel, $\frac{1}{2}$ of lumber used in conventional tanks and permits constructing larger capac. reservoirs than otherwise feasible. As hydrostatic pressure in any horizontal plane const. around tank perimeter, wall bands in tension only. Allowable stress reduced to permit initial bending due to curving staves to radius. Reduction about 4% for radius and stave thickness used. Verticals in tension except for moment developed through restraint at base. Point of inflection in verticals 2′ above tank bottom. Verticals attached to strap anchors with shear plates and lag screws to develop this restraint and meet tension induced by driving wedges and water uplifts. Tank laid out in 19 equal arcs each subtending 36° center angle. Foundation and bottom concrete. Bottom thickened at edges to receive anchors for 4′ × 6′ stiffeners. Latter and anchor straps joined as mentioned. Concrete slab poured, leaving grooves for calking and pockets for anchors grouted in. Inside 4′ × 6′ vertical stiffeners erected and braced; horizontal stave clamped thereto so that splice came as planned, then plank bent around vertical stiffeners and clamped at each. Connection made to next stave similarly bent and clamped. Operation repeated until entire band forced into place. Stave splices made with split rings and bolts. When all horizontal bands placed, outside 4′ × 6′ stiffeners erected and piece of end-grain fir set at top between stiffeners. Oaken wedges at top driven up, bottom joint calked with melted sulfur silica mixt. on inside and grout outside. Walls water-sprayed 2 days, then tank filled. Used std. 2′ × 6′ tongue-groove lumber dressed to $1\frac{5}{8}$″ thickness. No trouble bending staves to radius with relatively straight grain lumber. Slope of grain not over 1″ in 15″ adequate. All fabrication should have closer tolerances than for truss work. Bolt holes through staves must have driving fit.—*Ralph E. Noble.*

Concrete Reservoirs of the Vertical-Beam Type. C. MAXWELL STANLEY. Proc. A.S.C.E. **68:** 1679 (Dec. '42). Designer of concrete storage reservoirs must obtain watertight structurally safe reservoir at min. cost. Criteria of ideal wall design that will minimize and control cracks are: (1) concrete in contact with water must be in compression; (2) walls must be poured in sections sufficiently small to avoid excessive shrinkage cracks; (3) entire structure must be so designed that expansion and contraction may be controlled to avoid cracking of surfaces in contact with water; and (4) constr. joints must be kept to min., and each must be treated as expansion joint. Side wall acts as simple vertical beam, resisting internal water pressure, with horizontal reactions taken by suitable supports. Bottom of beam sets in recess in footing which is designed so that wall may rock slightly. Horizontal reaction at bottom is carried into footing, which is secured against horizontal movement. At top of wall, horizontal reaction is balanced against equal reaction at opposite wall, using roof slab or rods as ties between the two. Horizontal support of top of vertical beam relies on symmetry of structure, which permits balancing horizontal forces on opposite sides of reservoir. Bottom of vertical beam may be supported either by balancing opposing forces or by utilizing horizontal force resulting from reaction of wall on earth or rock or from friction on base. Corners of rectangular reservoirs are constructed with expansion joints arranged so that movement, or rocking, of wall will not be resisted by corners. Waterproofing required on wall at vertical expansion joints and at horizontal joints between footing and wall. Critical examn. of experiences with vertical-beam design reveals its advantages, as well as problems that have arisen. Conclusions may be drawn as follows: (1) Basic theory of vertical-beam reservoir sound. (2) Type offers extreme simplicity of both design and constr. (3) Constr. costs compare favorably with conventional types. (4) Design most aptly suited to rectangular reservoirs. (5) Design limited to depths such that vertical walls can be poured in one lift. (6) Type limited as to amt. of backfill that may be used on outside. (7) Type also probably limited to cases where good foundations available.—*H. E. Babbitt.*

War Manpower Commission

APPROVED LIST OF ESSENTIAL OCCUPATIONS

Group 30—Heating, Power, Water Supply and Illuminating Services

This list covers: electric light and power, water supply and gas utilities; steam-heating companies.

NOTE: Titles in the center column that are marked with an asterisk (*) are approved titles that do not as yet appear in Part 1 of the *Dictionary of Occupational Titles* or its Supplement. Definitions and code numbers for these titles are found at the end of this list. Titles that are identified by the abbreviation "ten." are those for which insufficient information was available to prepare complete definitions and codes; however, they will be prepared when sufficient information becomes available. Tentative definitions for these titles are also included at the end of this list.

EDITOR'S NOTE: The lengthy parenthetical explanations of a number of the titles in the left column, included in the original list, have been omitted from the following tabulation. These explanations may be found in the list of critical occupations included in "Occupational Bulletin No. 9, Amended January 19, 1943," for which *see* p. 375 of the March 1943 JOURNAL.

Common Title	*Dictionary Title*	*Code*
Accountant, Audit	Accountant, Audit	0–01.20
Armature Winder	Armature Winder, Repair	6–99.011
Auxiliary Equipment Operator (All Around)	Auxiliary Equipment Operator	ten.
Bacteriologist	Bacteriologist	0–39.36
Batteryman, Large Emergency Storage	Batteryman, Large Emergency Storage*	5–53.365
Blacksmith, Maintenance	Blacksmith II	4–86.010
Boiler Operator	Boiler Operator	ten.
Boilermaker, Maintenance	Boilermaker, Maintenance	4–83.100
Booster-Pump Operator	Booster-Pump Operator II*	7–72.520
Bricklayer, Maintenance Refractory	Bricklayer, Firebrick	7–24.110
Byproducts Operator, Gas	Byproducts Operator*	4–52.731
Cable Splicer	Cable Splicer II*	5–53.950

Carpenter, Maintenance	Carpenter, Maintenance	5–25.830
Chemist	Chemist, Organic	0–07.03
	Chemist, Physical	0–07.04
	Chemist, Water Purification*	0–07.21
Chief Operator, Water Purification or Softening	Purification-Plant Operator, Chief*	0–16.01
	Softening-Plant Operator, Chief*	0–16.01
Crane Operator	Electric-Gantry-Crane Operator	5–73.040
	Locomotive-Crane Operator	5–73.060
District Serviceman (Electric Power)	District Serviceman (Electric Power)	ten.
Draftsman, Engineering	Draftsman, Design	ten.
Driller, Water Well	Driller, Water Well*	5–75.232
Electrical Tester	Electric-Meter Tester	5–83.452
	Electrical Tester I	5–53.360
Electrician, System or Plant	Electrical Repairman	4–97.420
	Electrician	4–97.010
	Electrician, Power-House	4–97.510
Engineer, Professional and Technical	Civil Engineer	0–16.01
	Electrical Engineer	0–17.01
	Gas-Distribution Engineer	0–19.01
	Industrial Engineer	0–18.01
	Industrial-Power Engineer*	0–17.01
	Mechanical Engineer	0–19.01
	Right-of-Way Engineer	0–16.01
	Safety Engineer II	0–18.01
	Sanitary Engineer	0–16.01
Engineer, Turbine or Diesel	Diesel-Engine Operator, Stationary	5–72.210
	Generator Operator	5–51.110
	Stationary Engineer	5–72.010
	Turbine Operator	5–51.120
Foreman	Electrician, Chief I	4–97.420
	Electrician Foreman	4–97.010
	Foreman (light, heat and power)	5–95.320
	Foreman (water works)	5–95.340
Gas-Equipment-and-Control Man	Gas-Equipment-and-Control Man*	5–83.946
	Industrial-Gas Serviceman*	5–83.945
Gas Maker	Gas Maker	ten.
	Gas-Producer Man	6–56.010
Heavy Mobile Equipment Operator (Maintenance and Construction)	Trench-Digging-Machine Operator	5–23.030

Inspector	Inspector (light, heat and power)	ten.
Instructor, Training Program	Training Program-Instructor	ten.
Lead Burner	Lead Burner	4–95.031
Lineman	Lineman IV	5–53.420
	Trouble Man II	5–53.350
Load Dispatcher, Power or Gas	Gas Load Dispatcher	ten.
	System Operator	5–51.520
Machinist, Maintenance	Machinist II	4–75.010
Manager, Employment and Personnel	Manager, Employment	0–30.82
	Manager, Personnel	0–39.83
Mechanic, Maintenance	Maintenance Mechanic II	5–83.641
	Maintenance Pump Mechanic*	5–83.621
	Master Mechanic, Maintenance	5–83.641
	Pump Serviceman	5–83.641
Meter Repairman, Gas and Water	Gas-Meter Repairman	5–83.641
	Water-Meter Repairman	5–83.471
Patrolman, Transmission Line	Patrolman III*	7–53.415
Pipe Fitter, Maintenance	Pipe Fitter, Maintenance	5–30.010
	Steam Fitter	5–30.410
Purification Operator, Gas	Purification Operator	ten.
Pusher Man	Pusher Man I	6–56.030
Radio Technician	Communication Engineer*	0–61.85
	Inductive-Co-ordination Engineer*	0–17.81
	Radio Investigator*	0–17.01
	Radio Operator II	0–61.33
Rigger, Construction	Rigger III	5–88.020
Rigger, Supervisor, Underground Cable	Rigger, Underground Cable*	5–53.372
Sheet-Metal Worker, Maintenance	Sheet-Metal Worker, Maintenance	4–80.010
Storekeeper, Chief	Manager, Stockroom	1–38.50
Substation Operator	Substation Operator	5–51.210
Superintendent or Manager (Division, District, Plant and Department)	Superintendent or Manager (Division, District, Plant and Department)	ten.
Switchboard Operator	Power-Switchboard Operator III	5–51.130
System Operator (Load Dispatcher)	System Operator	5–51.520
Tree Trimming Supervisor (Overhead Power Lines)	Tree-Trimming Foreman	3–40.16
Welder (All Around)	Welder, combination	4–85.040

Definitions of Approved and Tentative Titles

Auxiliary-Equipment Operator (ten.): An operator who specializes in the operation, inspection, adjustment and repair of turbine and boiler auxiliaries, such as condensate pumps, condensers, fans, feed water pumps, pulverizers, oil coolers, fuel-oil pumps and air compressors.

*Batteryman, Large Emergency Storage** (5–33.365): Services and repairs large emergency storage batteries at an electric power station; checks concentration of electrolyte and periodically charges and discharges batteries; replaces faulty battery plates and other parts to keep batteries in good repair and ready for use during failure of normal source of supply.

Boiler Operator (ten.): Operates electric power station, central steam-heating station, gas plant or water pumping station boilers; watches for mechanical failures of boiler equipment as reflected by recording and indicating instruments and makes immediate adjustments to combustion-controls to maintain safe and efficient operation; makes minor repairs or replacement and assists with major repairs and routine tests; maintains log of instrument readings and operating changes.

*Booster-Pump Operator II** (7–72.520): Maintains and operates the pumps (m) at a pumping station along the main pipelines, used to boost oil or gas along the line to the next station; regulates force of pumping according to demand from stations ahead. May fire boilers of steam engine used to supply power to pumps (m), *ref.* "Fireman, Stationary Boiler."

*Byproducts Operator** (4–52.731): "A Still Operator (*chem.*)" who distills byproducts of the production of gas, such as oil, tar and ammonia, to manufacture saleable items. Usually specifically designated according to type of plant operated, as ammonia-house stillman, light-oil-plant operator, wash-oil-plant operator.

*Cable Splicer II** (5–53.950): Splices insulated copper wires to join two aerial, underground, buried or submarine multiple-conductor cables in order to preserve the continuity and insulation of each conductor; splices wires at junction of the two cables and insulates splices by drying out moisture, by wrapping with paraffin-soaked muslin and by covering splices with a lead sleeve (protective fitting over bundle of spliced wires); connects sleeve to cable sheathing by a lead joint; tests pairs of wire for electrical continuity and insulation by means of a buzzer system and connects wire ends to numbered terminals to give pairs the same identifying number at remote panel box as at the control office.

*Chemist, Water Purification** (0–07.21): "A Chemist, Inorganic," who tests, softens and purifies water in a water-purification plant by removing impurities, such as germs, salts and bacteria, using chemicals and laboratory devices; analyzes samples of filtered water to ascertain that quantities of solids left in suspension are below prescribed limits, using a special testing device called a turbidimeter; determines amount of liquid chlorine to be used in water-chlorinators to destroy harmful bacteria and germ-life, guided by findings of "Bacteriologist," softens water for industrial and do-

mestic use by removing dissolved minerals, acids and salts of iron, magnesium, calcium and other inorganic compounds, using chemicals and his knowledge of chemical precipitation and absorption methods; tests water samples extracted from various points in plant-distribution system, such as mains, tanks, pumps and outlets, to discover possible sources of contamination to purified water.

*Communication Engineer** (0–61.85): Tests, repairs and operates radio transmitting and receiving equipment and privately owned telephone systems; inspects and repairs radio receiving and transmitting apparatus, *ref.* "Radio Mechanic II"; tests and repairs telephone equipment to maintain private telephone systems, *ref.* "Telephone-Switchboard Repairman." May operate radio transmitter, *ref.* "Radio Operator I," and send and receive telegraphic messages, *ref.* "Telegraph Operator."

District-Service Man (Electric Power) (ten.): Maintains electric-power distribution systems in small or isolated communities by making repairs and replacements; erects power lines and installs related equipment, *ref.* "Lineman IV"; assists repair crews assigned for major jobs.

Draftsman, Design (ten.): A general term used to designate workers who make design drawings to assist in developing experimental ideas evolved by research engineers, using specifications and sketches, and employing his knowledge of engineering theory and its applications to solve mechanical and fabrication problems. Classifications are made according to work performed, as "Draftsman, Electrical," "Draftsman, Mechanical," "Draftsman, Structural."

*Driller, Water Well** (5–75.232): Locates and drills deep-water wells for use in supplying spring water to rural households and communities; determines location of subterranean springs for well-drillings by studying physical features of terrain and making test borings, *ref.* "Diamond Driller"; estimates water-well needs of specific localities to determine number, sizes and depths of drillings, considering factors, such as population load, area-size and methods and equipment used in distributing water, and employing his knowledge of water-supply problems; drills the wells, *ref.* "Well-Drill Operator," and supervises labor crews in installing subterranean pipes and screening equipment to be used in filtering water at well openings. May install subterranean and surface pumps used in operation of wells.

*Gas-Equipment-and-Control Man** (5–83.946): Tests, repairs and adjusts gas equipment in homes, *ref.* "Gas-Appliance Serviceman," and in commercial and industrial properties, *ref.* "Industrial-Gas Serviceman."

Gas Load Dispatcher (ten.): Supervises transmission and distribution of stored or purchased gas to insure an adequate supply to consumers, directing workers in maintaining proper pressure on all parts of pipeline system to take care of changing demands for gas at different periods of the day.

Gas Maker (ten.): Tends gas generating equipment, such as blowers, pumps, exhausters and waste heat boilers, to manufacture carburated water gas.

*Inductive-Co-ordination Engineer** (0–17.01): An "Electrical Engineer." Directs inductive-co-ordination sections of an electric power company in investigating and eliminating inductive

interference in transmission systems which cause radio-receiver interference; conducts technical investigations relating to inductive-co-ordination problems, including joint field investigations with engineers of communications and railroad companies; checks proposed parallels between power and communications circuits and recommends installation of facilities to eliminate or reduce inductive interference; consults with transmission and distribution line engineers on design of lines for prevention or reduction of radio interference; conducts research in detection and elimination of the causes of radio noises in transmission systems; assists municipalities in problems related to control equipment for alarm systems.

*Industrial-Gas Serviceman** (5–83.945): Tests, repairs and adjusts all types of industrial gas equipment, including complicated control mechanisms, such as thermostats, high-temperature-limit controls, solenoid valves, safety pilots and various other safety controls actuated by bimetallic expansion, fluid expansion or thermocouple electric energy.

*Industrial-Power Engineer** (0–17.01): An "Electrical Engineer." Consults with industrial power consumers, such as manufacturing plants, shipyards and railroads, to plan their needs and requirements for the use of electric power; inspects plants and their installations to determine methods of expanding existing power layouts, considering factors, such as electrical-load requirements, steam and heating needs and the use of special equipment for the manufacture of specified materials and products; examines engineering specifications for new plant structures and installations to determine most efficient and economical methods of laying out power-distribution equipment, such as transformers, feed-lines, auxiliary generators and switchboards; compiles reports and surveys on findings, including diagrams, statistics and charts for use by engineers authorized to install the equipment.

Inspector (ten.): Inspects installations and equipment of a public utility, such as power-plants, gas, steam, water and heating plants, underground lines and stations, to insure safe and efficient operation of the installations; inspects newly built plants and structures to insure close adherence to engineering specifications; examines plant operations to detect and record faults, such as unsafe or inefficient practices, remediable hazards and failure to comply with operating rules; confers with operating heads to assist in correcting faults or hazards observed; verifies correction or faults in subsequent inspections. May assist in starting operations in plants or may instruct personnel in operations until a plant reaches desired performance standards.

Instructor, Training Program (ten.): A term applied to competent workers who are detailed as instructors for established training programs in industrial plants to teach subjects and skills utilizing their own skills and knowledge.

*Maintenance Pump Mechanic** (5–83.641): A "Maintenance Mechanic II." Repairs subterranean pumps installed in bottoms of deep-water wells for use in supplying spring-water to rural households and communities; disassembles pump-machinery located at well-openings to detach shafting and plunger-rods from fittings, using

wrenches and hand-tools; directs labor crews in raising subterranean plunger-rods, shafting, reservoir cylinders and pumps to surface-levels, with the use of a hoist; inspects pump units and fittings to detect and repair faulty connections and parts, such as damaged or worn-out valves, machine screws, gears and springs; reinstalls pumps and fittings into well-bottom and tests their operations.

*Patrolman III** (7–53.415): Patrols electric transmission lines on foot, by automobile, boat or other means of transportation to inspect and report condition of transmission and distribution lines, sub-station and related equipment; inspects transmission and distribution lines; checks conditions of poles, guys and anchors; climbs poles or towers to inspect insulators, crossarms and conductors; prepares written reports on condition of equipment and evidence of encroachment of buildings or obstructions or conditions along right-of-way that might result in breakdown of electric service.

Purification Operator (ten.): Removes sulfur and other impurities from gas by operating liquid or oxide purification systems and tests gas after processing to determine that undesirable elements have been eliminated.

*Purification-Plant Operator, Chief** (0–16.01): A "Civil Engineer." A "Sanitary Engineer" who directs, controls and co-ordinates activities in a water-purification plant to treat and purify water for private, municipal or industrial use; supervises activities of "Water Filterers" engaged in purifying raw water passing through intakes, settling basins and filters; supervises floor crews in adjusting flow of chemicals into chlorinators to disinfect and sterilize water, following recommendations of "Chemist, Water-Purification"; directs and records findings of "Bacteriologist" in counting bacteria in water samples to insure uniform effectiveness of chlorination treatment; supervises maintenance men engaged in inspecting and repairing plant equipment, such as feed-lines, transmission mains and water-distribution outlets.

*Radio Investigator** (0–17.01): An "Electrical Engineer." Conducts field tests on electric power transmission systems, using portable radio receivers and other testing apparatus to locate faulty transmission equipment responsible for radio interference; initiates steps to correct causes of radio interference.

*Rigger, Underground Cable** (5–53.372): Determines and prescribes proper rigging equipment, set up and methods to be used in pulling underground power cables; arranges work of "Cable Pullers II" with regard to safety of men and care of materials and equipment.

*Softening-Plant Operator, Chief** (0–16.01): A "Civil Engineer." A "Sanitary Engineer" who directs, controls and co-ordinates water softening activities of a water purification plant to prepare water for domestic or commercial use; supervises floor-crews engaged in operating special equipment to remove iron, calcium and magnesium compounds from hard waters, using either the lime-soda precipitation process or the zeolite-mineral method (the use of an insoluble mineral to absorb hardening salts from water); directs and records findings of "Chemist, Water-Purification" in testing partially processed water to determine progress of water-softening treatment; supervises laborers engaged

in operating recarbonation devices that prevent formation of calcium deposits and incrustations in plant pipes.

Manager or Superintendent (Division, District, Plant and Department) (light, heat and power): Plans, directs and supervises activities of a major operating division, district, plant or department within a public-power utility, such as for heating, power, water supply or illuminating services; supervises recruitment and training of personnel; formulates or interprets company policies to obtain efficient operating procedures; reviews periodic reports to assist in solving administrative, organizational and technical problems; supervises and directs public relations activities.

*Tree Trimming Foreman** (3–40.16): Supervises "Tree-Trimming-Line Technicians" in clearing right-of-ways for high-voltage electric power lines; determines specific trees and tree-tops to be pruned, felled or repaired by trimming crews; directs crews in setting up climbing equipment to reach inaccessible branches and tree-tops; supervises crew activities in cutting away dead and excess branches to obtain safe clearance for wires and transmission towers. May direct activities of block-and-tackle crews in lowering dismembered tree-limbs from tree-tops to ground to prevent their contact with live-wires.

Recent Selective Service Amendments Relating to Occupational Deferment

EDITORIAL NOTE: Members of the A.W.W.A., who have occasion to present applications for occupational deferment for employees under Occupational Bulletin No. 9, should bear in mind that this series of amendments places the case within the jurisdiction of the appeal board in the area where the man now works. In case any water department has an "essential" employee who is now working in a locality different from that in which he originally registered for Selective Service, then the routine set forth in these amendments should be followed carefully. It is to be noted that under this procedure, if a registrant or an employer makes the first appeal to the original registration board and fails to request a transfer to the board having jurisdiction where the registrant is currently employed, any other request for transfer of appeal is prohibited.

Transfer of Appeal in Occupational Cases

(Effective March 13, 1943)

§ 627.71 *Request for transfer.* When an appeal is taken from the classification or reclassification of a registrant and when such appeal is upon the ground that the registrant should have been deferred by reason of his occupation, the appeal shall be transferred to the board of appeal having jurisdiction over the area in which the registrant is employed provided all of the following conditions are met (but not otherwise):

(1) The first person to appeal from such classification or reclassification files with his appeal a written request for such transfer;

(2) the written request states in what respect an occupation question is involved; and

(3) the written request states the name of the registrant's employer and the street address, county, and State where the registrant is employed.

2. Amend the regulations by adding a new section to be known as § 627.72 to read as follows:

§ 627.72 *Procedure when request for transfer is made.* (a) When a request for transfer of appeal has been made under the provisions of § 627.71, the local board shall forward the registrant's file to its State Director of Selective Service.

(b) When the State Director of Selective Service receives the file of a registrant which has been forwarded under the provisions of paragraph (a) of this section, he shall forward the file either (1) to the board of appeal in his State which has jurisdiction over the registrant's place of employment when such place of employment is within his State, or (2) to the State Director of Selective Service for the State in which the registrant is employed for transmittal to the board of appeal having jurisdiction over such place of employment. The transfer board of appeal shall act on the appeal in the same manner and make the same entries in its records as it makes in the case of an appeal from a local board whose records it normally reviews except that all entries will be made in red ink.

(c) When the transfer of appeal has acted upon such an appeal, it shall return the file to its State Director of Selective Service who will forward the file either (1) to the local board of origin when it is located within his State, or (2) to the State Director of Selective Service of the State in which the local board of origin is located for transmittal to such local board of origin.

Appeal to The President in Occupational Transfer Cases

(Effective March 13, 1943)

§ 628.1–1 *Appeal to the President in occupational transfer cases.* When, under the provisions of §§ 627.71 and 627.72, a registrant's case has been transferred to a board of appeal having jurisdiction over the area in which the registrant is employed, and such board of appeal is in a different State from the local board of origin, either the State Director of Selective Service of the State in which the local board of origin is located or the State Director of Selective Service of the State in which the transfer board of appeal is located may appeal to the President from the determination of the transfer board of appeal if he deems it to be in the national interest or necessary to avoid an injustice.

Jurisdiction of Boards of Appeal

(Effective March 15, 1943)

§ 603.24 *Jurisdiction.* Each board of appeal shall have jurisdiction to review and to affirm or change any decision appealed to it from any local board in its area or any decision appealed from any local board not in its area when transferred to it in the manner provided in these regulations.

[Reprinted from the *Federal Register* of March 16 and 17, 1943]

Decentralization of War Production Board Activities

SINCE a War Production Board policy of decentralization was announced ten months ago, the field offices have been assuming an increasing number of activities hitherto centered in Washington.

The processing of PD–1A forms within certain limitations is one of the major aspects of the WPB decentralization affecting water works. This matter is covered in detail in the text portion of this JOURNAL. Functions of these district offices are wide and varied, ranging from promoting conservation programs to assisting in labor relations or helping small plants obtain war work.

There are 12 regional offices, each located in a key city: Boston, New York, Philadelphia, Atlanta, Cleveland, Detroit, Chicago, Minneapolis, Kansas City, Dallas, Denver and San Francisco. These are supervisory, parent offices whose main job is to administer 131 district offices and to co-ordinate the service provided to the public through these district offices. In some cases, the field office is a district and regional office combined, some members of the staff carrying on the supervisory functions while others attend to the operations of the branch. The field offices employ some 6500 people selected chiefly on the basis of their understanding of local problems. These people handle more than a million contacts a week.

A typical regional office has 13 departments:

1. The Director's Office is responsible for the direction of all field activities in a given geographical area.

2. The Administrative Office assists the Director's Office.

3. The Statistics Dept. obtains facts, summaries, etc.

4. Labor Production Representatives serve as a focal point for labor unions, management and government.

5. The Priorities Dept. exercises control over uses and distribution or flow of materials.

6. The Compliance Dept. sees to it that all WPB orders and regulations are complied with.

7. The Conservation Div. helps initiate and promote salvage and scrap campaigns not only in industrial organizations but also in homes—for fats, greases, tin cans, etc.

8. The Appeals Dept. receives and checks appeals for exemption from conservation or limitation orders.

9. The Smaller War Plants Div. maintains direct contact with distressed plants and with district procurement officers of the Army and Navy. It surveys plants and develops production programs into which small plants can fit.

10. The Production Service Dept. works co-operatively with the Smaller War Plants Div.

11. The Governmental Dept. works with state and local governments in obtaining their requirements of materials and equipment.

12. The Legal Dept. advises the Regional Director on all legal matters, interpretations of orders, etc.

13. The Redistribution Dept. has the job of locating, obtaining and redistributing idle and excessive inventories of critical materials, equipment and machinery.

Revision of Form PD-1A and Filing in WPB Regional Offices

WAR Production Board Form PD–1A, "Application for Preference Rating," was revised on the basis of suggestions from industry representatives and the WPB Industry Div., according to WPB Release 2685. Copies of the revised form have been available from WPB field office since March 1.

PD–1A applications on the old forms were processed until April 1, but after that date the use of the new forms was mandatory.

The chief change in the form was from the column-type, with accompanying instruction sheet, to a block type of question and answer form designed to facilitate application and to reduce to a minimum special requests for additional information. A clearance form used in processing the application was also incorporated to speed handling and some questions, not previously asked, were added to eliminate need for supplemental forms.

Beginning on March 1, all PD–1A applications were required to be filed with the nearest WPB *District* Office, not in Washington.

After March 15, all applications for ratings on *less than $100 worth* of material were processed in the WPB *Regional* Offices. This preliminary value limitation has been established with the plan of progressively increasing it as the Regional Offices assume greater responsibilities. It is expected that by mid-April more than 80 per cent of all PD–1A applications will be handled entirely in the field.

It is to be noted that WPB Bulletin 2344 of January 8, 1943, cited the authorization of WPB *Regional* Offices to assign AA–1 priority ratings up to a value of $500 in case of emergencies.

EDITOR'S NOTE: While the above is official at the date of this JOURNAL's going to press, there is a strong probability that requests for material related to the Office of War Utilities will, if on form PD–1A, be re-routed to that Office *or* that, later, a new form of application may be developed for the use of utilities only. Such changes, when officially promulgated, will be brought to the attention of A.W.W.A. members.

Water Works Maintenance Policy

As Affected by the War Production Board

By Harry E. Jordan

WHEN the Director of War Utilities promulgated Order U–1 on February 24, the members of the American Water Works Association were sent copies of the Order together with certain interpretative comments prepared by the writer. It had been the intention to publish the Order in this issue of the JOURNAL and to extend the comments for the further guidance of water works executives.

It is now [March 31, 1943] reliably indicated that Order U–1 will be revised, but probably not in time for promulgation when the call is issued for the 193B reports for the first quarter of 1943. These reports, it will be remembered, are now required only from plants serving 50,000 or more persons.

It is not proper to record with any degree of exactness what changes are contemplated. Representations have been made by several groups to the effect that the language of the order is unduly complicated. It has also been claimed that the restrictions on purchase, use and inventory are so severe as to jeopardize the continuation of service. Especially in the class of distribution materials, the restriction of inventory to an amount related to 1942 use brings emergency reserve materials to a point so low that many water works superintendents are frankly fearful of their ability to meet any real emergency involving pipe, valves and fittings. Likewise it has been said that certain materials used in water works construction are by no means so scarce as the limitations of the order indicate.

Without making editorial comment upon these statements at this time, suffice it to say that there is so definite prospect of a revision of U–1 that interpretations of it, as it now is written, verge upon the academic—even though the problems created for water works men by the order are not academic but serious.

From the 193B reports filed by the larger water utilities (serving more than 56½ millon of the 83–84 million persons who receive public water supply) a series of tabulations has been made. They are expressed in "dollars per 1000 population served" so that the manager of any water department can compare these basic records with his own city's record by simple factoring. These tables appear herewith and should be studied carefully by every water works man. The tables show what was used in 1940, what the inventory was at the end of 1940 and what the successive quarters of 1942 record for purchase, use and inventory.

The questions that all must analyze seriously and without prejudice are:

Are water utilities being maintained at a level sufficient to meet wartime needs?

Is the permitted reserve inventory large enough to meet emergency conditions?

Should water utilities, in the public interest, be permitted a more nearly normal maintenance, repair and operation program?

These tabulations are placed before water works men, and the questions are outlined in the hope that study will be given to them. The attitude that water works men take toward War Production Board orders must be based upon full consideration of the facts as they affect the water supply service. They must also satisfy themselves that their supplies and services bear proper relationship to the war activities in their communities and that such war work is not in danger from failure of or interruption to the water service.

Water Works Inventory

At End of Period Noted; in Dollar Value per 1000 Population Served; Q = Quarter

Classification of Equipment, Materials, Supplies and Repair Parts	1st Q. 1942	2nd Q. 1942	3rd Q. 1942	4th Q. 1942	Q. Avg. Last 3 Q. 1942	All 4 Q.	End of Year 1940
Total Fuel	19.86	21.49	25.74	26.38	24.54	23.37	16.01
Materials for Source of Supply							
Equipment Parts & Materials	11.40	12.42	10.46	7.82	10.23	10.53	12.05
Other Materials & Supplies	7.33	5.82	5.42	4.47	5.24	5.76	6.51
Total for Source of Supply	18.73	18.24	15.88	12.29	15.47	16.29	18.56
Total Purif. Materials & Supplies	17.66	17.25	17.49	19.73	18.16	18.03	14.90
Meters	43.18	41.81	34.15	24.21	33.39	35.84	35.56
Transmission & Distribution Materials & Supplies							
Cast-Iron Pipe	111.68	107.97	70.40	62.24	80.20	88.07	108.90
Steel & Wrought Iron Pipe	9.68	9.55	7.13	4.95	7.21	7.83	7.48
Copper & Brass Pipe & Tubing	9.42	7.12	4.64	3.50	5.09	6.17	6.46
Lead Pipe	2.68	2.37	2.38	2.67	2.47	2.53	1.51
Pipe Fittings	69.22	65.38	55.30	46.97	55.88	59.22	65.34
Valves & Valve Parts	35.29	33.66	27.75	23.73	28.38	30.11	31.43
Hydrants	9.40	7.92	6.61	5.67	6.73	7.40	8.25
Parts for Meters & Hydrants	27.68	29.12	28.92	25.23	27.76	27.74	27.62
Other Trans. & Dist. Materials & Supplies	36.44	33.41	28.26	22.14	27.94	30.06	44.15
Total of Trans. & Distr.	311.49	296.50	231.39	197.10	241.66	259.13	301.14
Other Materials & Supplies	16.64	17.76	14.21	15.66	15.88	16.07	14.40
Total of All Items	427.56	413.05	338.86	295.37	349.10	368.73	400.57
Excess		23.19	64.68	88.86			
Total	427.56	436.24	403.54	384.23	349.10	368.73	400.57
Population Served	54,700,000	55,000,000	57,500,000	41,000,000			50,200,000
No. Utilities Reporting	232	231	236	189			235

Deliveries to Water Works

During Period Noted; in Dollar Value per 1000 Population Served; Q = Quarter

Classification of Equipment, Materials, Supplies and Repair Parts	1st Q. 1942	2nd Q. 1942	3rd Q. 1942	4th Q. 1942	Total 1942	Q. Avg Last 3 Q. 1942
Total Fuel	36.61	34.28	35.90	29.09	135.88	33.09
Materials for Source of Supply						
Equipment Parts & Materials	4.39	5.81	3.93	3.24	17.37	4.33
Other Materials & Supplies	3.90	3.63	2.46	2.39	12.38	2.83
Total for Source of Supply	8.29	9.44	6.39	5.63	29.75	7.16
Total Purif. Materials & Supplies	22.05	20.54	24.34	22.42	89.35	22.43
Meters	12.31	10.56	6.27	4.00	33.14	6.94
Transmission & Distribution Materials & Supplies						
Cast-Iron Pipe	18.47	11.82	5.10	4.68	40.07	7.20
Steel & Wrought Iron Pipe	1.91	1.99	1.00	0.26	5.16	1.08
Copper & Brass Pipe Tubing	1.45	0.27	0.08	0.02	1.82	.12
Lead Pipe	0.92	0.77	0.87	0.48	3.04	.71
Pipe Fittings	5.44	4.47	2.22	1.87	14.00	2.85
Valves & Valve Parts	5.04	4.08	1.75	1.34	12.21	2.39
Hydrants	2.82	1.25	0.55	0.54	5.16	.78
Parts for Meters & Hydrants	5.76	5.39	3.96	3.43	18.54	4.26
Other Trans. & Dist. Materials & Supplies	11.42	9.11	7.19	3.90	31.62	6.73
Total of Trans. & Distr.	53.23	39.15	22.72	16.52	131.62	26.12
Other Materials & Supplies	9.70	9.11	5.44	6.08	30.33	6.88
Total of All Items	142.19	123.08	101.06	83.74	450.07	102.62
Population Served	54,700,000	55,000,000	57,500,000	41,000,000		
No. Utilities Reporting	232	231	236	189		

Withdrawals From Water Works Inventory

During Period Noted; in Dollar Value per 1000 Population Served; Q = Quarter

Classification of Equipment, Materials, Supplies and Repair Parts	1st Q. 1942	2nd Q. 1942	3rd Q. 1942	4th Q. 1942	Total 1942	Q. Avg. Last 3 Q. 1942	Year 1940
Total Fuel	36.17	31.51	32.36	29.70	129.74	31.19	32.41
Materials for Source of Supply							
Equipment Parts & Materials	4.45	5.68	3.69	3.12	16.94	4.16	6.10
Other Materials & Supplies	3.91	3.46	2.52	2.25	12.14	2.74	4.73
Total for Source of Supply	8.36	9.14	6.21	5.37	29.08	6.90	10.83
Total Purif. Materials & Supplies	20.89	20.16	22.54	21.84	85.43	21.51	19.87
Meters	10.66	12.95	9.12	4.89	37.62	8.99	12.58
Transmission & Distribution Materials & Supplies							
Cast-Iron Pipe	13.65	9.19	5.99	4.13	32.96	6.44	35.03
Steel & Wrought Iron Pipe	1.29	1.44	1.09	.43	4.25	.99	2.30
Copper & Brass Pipe & Tubing	1.68	1.45	.68	.35	4.16	.83	3.40
Lead Pipe	.56	.82	.65	.47	2.50	.64	.67
Pipe Fittings	4.28	4.18	2.71	2.21	13.38	3.03	7.45
Valves & Valve Parts	2.98	3.73	2.20	1.68	10.59	2.54	6.19
Hydrants	2.07	2.00	1.30	.90	6.27	1.40	3.48
Parts for Meters & Hydrants	5.36	5.08	4.09	3.65	18.18	4.27	7.06
Other Trans. & Dist. Materials & Supplies	9.50	10.43	7.65	4.40	31.98	7.49	16.96
Total of Trans. & Distr.	41.37	38.32	26.36	18.22	124.27	27.63	82.54
Other Materials & Supplies	9.61	9.49	5.86	6.12	31.08	7.16	9.72
Total of All Items	127.06	121.57	102.45	86.14	437.22	103.38	167.95
Population Served	54,700,000	55,000,000	57,500,000	41,000,000			
No. of Utilities Reporting	232	231	236	189			

Limitations on the Use of Copper

The following regulations of the Copper Branch need to be kept in mind, for these are effective regardless of other WPB orders such as Utilities Order U–1, for instance.

Order M–9–c (As Amended February 26, 1943)

As set forth in List A–2, this conservation order prohibits the manufacture of copper or copper base alloy "pipe, tube, tubing and fittings for water supply and distribution systems and installations *except* corporation stops and couplings therefor, curb stops and couplings therefor, adapters, unions, solder nipples and ferrules *and except* for all such pipe, tube, tubing and fittings for use on board ship and *in chlorine gas equipment.*"

Order M–9–c (Issued October 27, 1942, and Amended November 18, 1942)

This conservation order restricting the use of copper in the building industry includes the following restrictions which pertain to some operations of the water works field:

"(b) *Restrictions on installation.* Notwithstanding any contract or agreement to the contrary or the receipt of any preference rating other than one described in paragraph (b)(4) hereof, on and after October 27, 1942, no person shall install in or connect to a structure or system (as such operations are defined in paragraph (a)(9) of this order) any copper or copper base alloy pipe, tubing fittings or building material, except that:

(1) Any person may install in or connect to a structure or system any copper or copper base alloy pipe, tubing or building material in any aggregate amount not in excess of 25 pounds for each necessary repair of a structure or system, provided that such pipe, tubing or building material is used to repair or replace copper or copper base alloy pipe, tubing or building material and provided that such pipe, tubing or building material was, on or before October 26, 1942, in the possession of the person owning the structure or system; and

(2) Any person may connect for purposes of repair and maintenance copper or copper base alloy fittings to copper water tubing already installed; and any person may connect for any purpose copper or copper base alloy fittings to a water supply or distribution system outside of a building; and

(3) [Relates to Army and Navy installations.]

(4) Any person may install in or connect to a structure or system any copper or copper base alloy pipe, tubing, fittings or building material (i) upon the written authorization of the Director General for Operations given under this order authorizing the specific installation, or (ii) pursuant to a specific authorization, or preference rating certificate or order constituting authorization, to begin construction pursuant to the provisions of Conservation Order L–41, as amended from time to time. Applications for authorization under this order may be made by letter, setting forth the reasons why the person believes such material should be installed in or connected to a building."